I. C. ELECTRICIAN
I & C

NAVY TRAINING COURSES

NAVPERS 10557

I. C. ELECTRICIAN 1 AND CHIEF

Prepared by
BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES
NAVPERS 10557

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PREFACE

This book is written for men of the United States Navy and Naval Reserve who are interested in qualifying for advancement to I.C. Electrician 1 and Chief. Combined with the necessary practical experience, this training course, which deals chiefly with electromechanical components, particularly automatic telephones in the last five chapters, will prepare the reader for the advancement-in-rating examination.

The qualifications for I.C. Electricians are listed in appendix II. This training course contains information on each examination factor of the qualifications for I. C. Electricians 1 and Chief. Because examinations for advancement are based on these qualifications, interested personnel should refer to them frequently for guidance.

I. C. Electrician 1 and Chief was prepared by the United States Navy Training Publications Center, which is a field activity of the Bureau of Naval Personnel. Technical assistance was provided by the staff of the United States Naval School, I. C. Electricians, Class B, United States Naval Receiving Station, Washington, D.C. and by other Navy activities cognizant of I. C. equipment and the duties of I. C. Electricians.

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ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E-2 or 8 mos. total service.	6 mos. as E-3 or 14 mos. total service.	12 mos. as E-4.	12 mos. as E-5; total service at least 36 mos.	36 mos. as E-6.
SCHOOL	Recruit Training.		Class A for PR3, PRS3.		Class B for MN1.	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.			
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.				
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.				
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center			BuPers
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
	FOR THESE DRILLS PER YEAR						
TOTAL TIME IN GRADE	24 OR 48 12 NON-DRILLING	9 mos. 9 mos. 12 mos.	9 mos. 15 mos. 24 mos.	15 mos. 21 mos. 24 mos.	18 mos. 24 mos. 36 mos.	24 mos. 36 mos. 48 mos.	36 mos. 42 mos. 48 mos.
DRILLS ATTENDED IN GRADE#	48 24 12	27 16 8	27 16 13	45 27 18	54 32 20	72 42 32	108 64 38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48 12 NON-DRILLING	14 days 14 days None	14 days 14 days None	14 days 14 days 14 days	14 days 28 days 14 days	28 days 42 days 28 days	42 days 42 days 28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Active duty periods may be substituted for drills and training duty.

READING LIST

NAVY TRAINING COURSES

I.C. Electrician 3, NavPers 10555
I.C. Electrician 2, NavPers 10556
I.C. Electrician 1 & C NavPers 10557
Basic Hand Tool Skills (Metal Working Skills Only) NavPers 10085
Basic Electricity, NavPers 10086
Basic Electronics (less chapter 14) NavPers 10087
Naval Electronics, Part 3 (chapter 6) NavPers 10810

OTHER PUBLICATIONS

Bureau of Ships Manual, chapters 4; 45; 60 (sections III, IV, parts 4, 6, 7); 61; 62 (sections I, III); 63; 65; 69; 85
U.S. Navy Safety Precautions (chapter 18) OpNav 34Pl

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your information and Education Officer.[1] The following is a partial list of those courses applicable to your rate:

SELF TEACHING

Number	*Title*
MA 784	*Electric Wiring*
MB 290	*Physics I (Mechanics)*
MB 785	*Electrical Measuring Instruments*
MB 858	*The Slide Rule*

CORRESPONDENCE

CB 290	*Physics I (Mechanics)*
CB 785	*Electrical Measuring Instruments*
CB 858	*The Slide Rule*

[1] "Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified on the active duty orders."

I. C. ELECTRICIAN

1 AND CHIEF

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CHAPTER 1

ORGANIZATION AND ADMINISTRATION

INTRODUCTION

The purpose of this training course is to aid the IC2 in preparing for advancement to IC1. It will likewise aid the IC1 in preparing for advancement to ICC. The trainee should realize, however, that training for IC1 or ICC entails more than the mere reading of a training course. Certain practical factors can be acquired only by working with equipment. Intangibles, such as tact, leadership, and the ability to make sound decisions, depend to a great extent on the thinking and accumulated experiences of the individual.

The United States Navy offers a wonderful opportunity for advancement to the IC who is alert and keeps abreast of the rapid progress in his field. This keeping abreast of progress requires reading and studying of additional material to that contained in a training course. Numerous commercial textbooks and periodicals are available that will be of general interest to the IC to supplement the films and technical publications listed in this training course.

The *Manual of Qualifications For Advancement In Rating*, NavPers 18068, contains the military requirements and the professional qualifications for the various ratings in the Navy. To keep this manual up to date, the Bureau of Naval Personnel issues periodic changes which include

additional skills, and techniques required for new equipment.

The professional qualifications for I.C. Electricians are listed in appendix II and include Change No. 1, dated 1 February 1954. Personnel preparing for any examination subsequent to the date of this change should refer to the latest revision of the *Manual of Qualification for Advancement in Rating.*

The *Record of Practical Factors,* NavPers 760, contains the practical factors for the military and professional requirements for each general service rating. This form is used by the supervising officer of each man. When the man qualifying for a rate has demonstrated proficiency in the performance of the practical factor, the supervising officer enters his initials and the date in the appropriate columns provided on this form. When an enlisted man is transferred, the supervising officer's copy of the form is signed, inserted in the correspondence side of the enlisted service record, and forwarded.

The *Training Courses and Publications for General Service Rating,* NavPers 10052-D, is an annual bibliography which is published for the use of all Naval personnel concerned with advancement in rating examinations. This bibliography contains the Navy training courses and other appropriate training publications for which a man is responsible when preparing for a particular rate.

The first chapter of this training course presents information concerning the Electrical Division and its administration. Also presented are suggestions of a general nature regarding supervision, leadership, and training. Additional information concerning these subjects can be obtained from other Navy publications. A practical I.C. Group organization plan within the E Division and a training bill are delineated. These can be considered as representative, but are not to be considered as adequate or even feasible under all circumstances.

Another chapter contains the theory and practical ap-

plication of gas-filled electron tubes. This discussion is a continuation of gas-filled tubes contained in *Basic Electronics,* NavPers 10087, and is treated at the technician's level. A more rigorous treatment can be found in commercial textbooks.

Basic mechanisms that comprise many mechanical components of I.C. instruments are discussed. These include shafts, gears, differentials, cams, servomotors, follow-up controls, counters, and friction-disk and roller assemblies.

A detailed description of various I.C. instruments classified under the Ship's Metering and Indicating System is included. These are shaft-revolution, wind-direction and speed, salinity, and underwater-log indicator systems.

The IC must become acquainted with each new development in his field. Accordingly, this training course includes chapters on the theory and actual applications of magnetic amplifiers. If the IC understands the basic principles sufficiently well, he can utilize manufacturers' instruction books and other sources of information to advantage in servicing the newer equipments. As with all I. C. service work, the knowledge of basic principles must be supplemented by practical experience.

The explanation of gyrocompass equipment is a continuation of the discussion of gyrocompasses contained in *I.C. Electrician 2,* NavPers 10556. The control, alarm, followup, and transmission systems of the Sperry Mk XI Mod 6 and the Arma Mk VIII Mod 3A gyrocompasses are explained.

Other chapters contain the theory, the principles, and the operation of the dial telephone system. This information includes detailed descriptions of the various components of the system, such as relays, switches, line station equipment, and the automatic switchboard.

ASPECTS OF SHIPBOARD ORGANIZATION

United States Navy ships are operated in accordance with a standard shipboard organization that provides for

the development and maintenance of the proper relationships between the material elements and the human elements to accomplish (with maximum economy and efficiency) the intended objectives of the ship. The aspects of shipboard organization are the (1) MECHANICAL elements that comprise the organization structure and (2) DYNAMIC elements that concern the integration of the human factors into this structure.

Mechanical Aspects

The mechanics of the ship's organization concerns the establishment of the mechanical framework within which the various material (functional) elements are related. In this sense, "organization" is defined as determining the activities that are necessary to any purpose and arranging them in groups that may be assigned to individuals. The organization structures for BATTLE, for ADMINISTRATION, and for WATCHES in the various ship's organization manuals represent the mechanical aspect of shipboard organization.

ORGANIZATION CHARTS.—Organization charts are used to present graphically the arrangement of the departments, divisions, and billets for the line and staff relationships of all personnel in the organization. Thus, the organization chart provides the personnel with a concise picture of the relationships of individuals within the organization.

Dynamic Aspects

The dynamics of the ship's organization concerns the organizing of the human factors according to the qualifications of the individuals. In other words, the dynamics of organization are primarily concerned with "organizing people." The assignment of personnel through the Watch, Quarter, and Station Bill represents the dynamic aspect of shipboard organization.

FUNCTIONAL GUIDES.—Functional guides (job descriptions) are used to present the broad objectives of a specific

billet to distinguish it from all other billets. These guides constitute a formal directive to the officers and petty officers at all levels detailed to particular billets concerning their responsibilities, authority, and position in the ship's organization.

Ship's Organization Manuals

Maximum efficiency of operation is achieved through a clear understanding of the functional relationships of the ship's organization. The details of this organization are promulgated to the ship's personnel through the *Ship's Organization and Regulations Manual* and supplementary Department and Division Manuals that contain organization charts and functional guides through all supervisory levels in the administrative organization of the ship.

SHIP'S ORGANIZATION AND REGULATIONS MANUAL.—The *Ship's Organization and Regulations Manual* is the basic directive that governs the internal administrative and watch organization of the ship. It also governs the coordination of departments in general and in emergency conditions, and the conduct of personnel aboard ship.

The primary purpose of the *Ship's Organization and Regulations Manual* is to provide the ship's personnel with a ready source of authoritative information concerning their duties, responsibilities, and authorities in administering and operating the ship. This manual establishes the ship's (1) administrative organization, (2) watch organization, (3) organization bills, and (4) regulations.

DEPARTMENT AND DIVISION ORGANIZATION MANUALS.—The Department and Division Organization Manuals contain organization charts and functional guides through all supervisory levels to supplement the *Ship's Organization and Regulations Manual.* These manuals include more detailed information concerning the responsibilities and authority in both the administrative and watch organizations of the department or division.

The two primary purposes of the Department and Division Organization Manuals are to delegate the authority

of department heads or division officers, and to assign duties and responsibilities to subordinates. These manuals contain only organization charts and functional guides and do not prescribe department or division procedures.

The material included in the Department and Division Organization Manuals will vary within each department and division according to the type of ship. In large departments, the Department Organization Manual may only prescribe the delegation of authority by the head of the department to his key subordinate officers, and the Division Organization Manual may be necessary to delegate authority through the petty officer levels. On the other hand, in small departments, the Department Organization Manual may also serve as the Division Organization Manual.

Ship's Personnel Bills

ORGANIZATION BILLS.—The Ship's Organization Bills contained in the *Ship's Organization and Regulations Manual* include the department or division requirements of personnel to be furnished for various general and emergency conditions. Heads of departments and division officers can, by reference to the bills, assign personnel by names to fill stations indicated in the Ship's Organization Bills. The Division Officer, using his division notebook and the Watch, Quarter and Station Bill, must keep the assignments current and ensure that all personnel are informed of those assignments. The assignment to duty in a Ship's Organization Bill is normally indicated in the Watch, Quarter, and Station Bill (fig. 1–1) by a notation of the station assigned, or the duty to be performed, opposite the man's name in the columns headed by the applicable Ship's Organization Bills.

PERSONNEL ASSIGNMENT BILL.—The Personnel Assignment Bill of the *Ship's Organization and Regulation Manual* establishes the responsibilities and procedures for the assignment and reassignment of officers and enlisted per-

PAGE NOT AVAILABLE

EMERGENCY

GENERAL EMERGENCY			FIRE				MAN-OVERBOARD	
EMERGENCY (ABANDON SHIP ETC.)		OWN SHIP SALVAGE DETAIL	UNDERWAY		IN PORT			
STATION	PROVIDE		STATION	PROVIDE	STATION	PROVIDE	STATION	PROVIDE
AREA #3	—	—	—	—	—	—	—	—
AREA #3	—	—	—	—	—	—	—	—
AREA #3	—	—	—	—	—	—	—	—
AREA #3	—	FWD EMER. DIESEL	SCENE	ELECT KIT	SCENE	ELECT. KIT	—	—

sonnel to billets within the ship's organization, including collateral and special duties.

PERSONNEL ALLOCATION LIST.—The Personnel Allocation List provides a detail, or breakdown of the allowance or complement list to departments, divisions, and the three watch sections of the ship. This breakdown represents a logical assignment of rates and ratings to departments and divisions of the ship's organization so that all enlisted personnel are divided into approximately equal portions among the three watch sections. These lists are classified CONFIDENTIAL because information concerning the allowance and complement of the vessel is contained in this breakdown. The Personnel Allocation List is promulgated to the ship's company through the ship's Battle Organization Manual.

ASSIGNMENT OF PERSONNEL

The complement and allowance of personnel of Navy ships are accomplished by both the Chief of Naval Operations and the Chief of Naval Personnel. The Chief of Naval Operations determines the number of men to be assigned to a particular ship, and the Chief of Naval Personnel determines the ranks and ratings of these officers and men.

Complement

The complement of a combat ship is based on the number of personnel required to (1) man the stations for battle, (2) perform the basic administrative requirements, and (3) maintain the continuous watches required under wartime conditions of readiness. The complement is, therefore, a fixed number based on the mission and the installed equipment of the ship.

Allowance

The allowance of a combat ship is based on a percentage of the complement necessary to maintain and operate the

ship under peacetime conditions. The allowance is a flexible component in personnel administration based on national policy and budgeting limitations. It should be understood that a ship with peacetime allowance is still a very effective fighting unit. However, in the event of an emergency the prevailing allowances of ships are expanded to wartime complements as quickly as possible.

Section

For wartime organization, each division is divided into three approximately equal sections, each being adequate to maneuver and fight the ship under emergency conditions. The section is the primary organization unit of the ship for administration of condition watches, watch standing, liberty, and messing and berthing. Each section should include an adequate number of qualified rated and nonrated personnel to man all required stations in emergencies, including those stations for getting under way and proceeding to sea for limited operations as may be required by the weather, surprise hostile activity, or other emergency situations.

Two primary considerations in the assignment of personnel in the organization structure are the number and qualifications of the available personnel that must be employed in the various battle, watch, and administrative billets to effectively fulfill the mission of the ship, department, or division.

Officer Assignments

The assignment of officers to primary, collateral, and concurrent duties is published in the Ship's Roster of Officers, the departmental Watch, Quarter, and Station Bills, and supplementing watch and duty lists.

Enlisted Assignments

The assignment of enlisted personnel is accomplished through the use of divisional, sectional, watch, and billet number assignments. Assignments to the various billets

prescribed by the Ship's Battle Bill, Ship's Watch Organization, Ship's Organization Bills, and departmental and divisional administrative and watch organizations are published in the division Watch, Quarter, and Station Bill (fig. 1–1), and supplementing watch and duty lists.

Ships seldom experience the ideal conditions presented by the Personnel Allocation List because of unavoidable fluctuations in the ranks and ratings onboard and because of differences in (1) the capabilities of individuals, (2) material resulting from improvements and alterations, and (3) operating conditions. Hence, division officers will be required to modify assignments of personnel to stations and duties in places where these inconsistencies occur. Necessary appraisals and revisions must be made continuously of the various assignments to achieve maximum operational efficiency and optimum utilization of personnel.

The Division Officer's Notebook and individual watch, quarter, and station cards are used to advantage for controlling, recording, and disseminating information on such assignments. The procedures for the use of these techniques are published in NWP50 *(Naval Warfare Publication)*, Shipboard Procedures, and the Division Officer's Guide.

ELECTRICAL DIVISION ORGANIZATION

The scope of this training course does not permit a description of the entire ship's organization, which is published in *United States Navy Regulations* and more specifically in the previously mentioned *Ship's Organization and Regulations Manual.* However, a brief description of the Electrical Division is included with particular emphasis on the duties and responsibilities of the I. C. Electricians who are members of this division and who are under the direct supervision of the Electrical Officer, or when assigned, the division Material Officer. A sample organization of an Electrical Division is illustrated by the organization chart in figure 1–2.

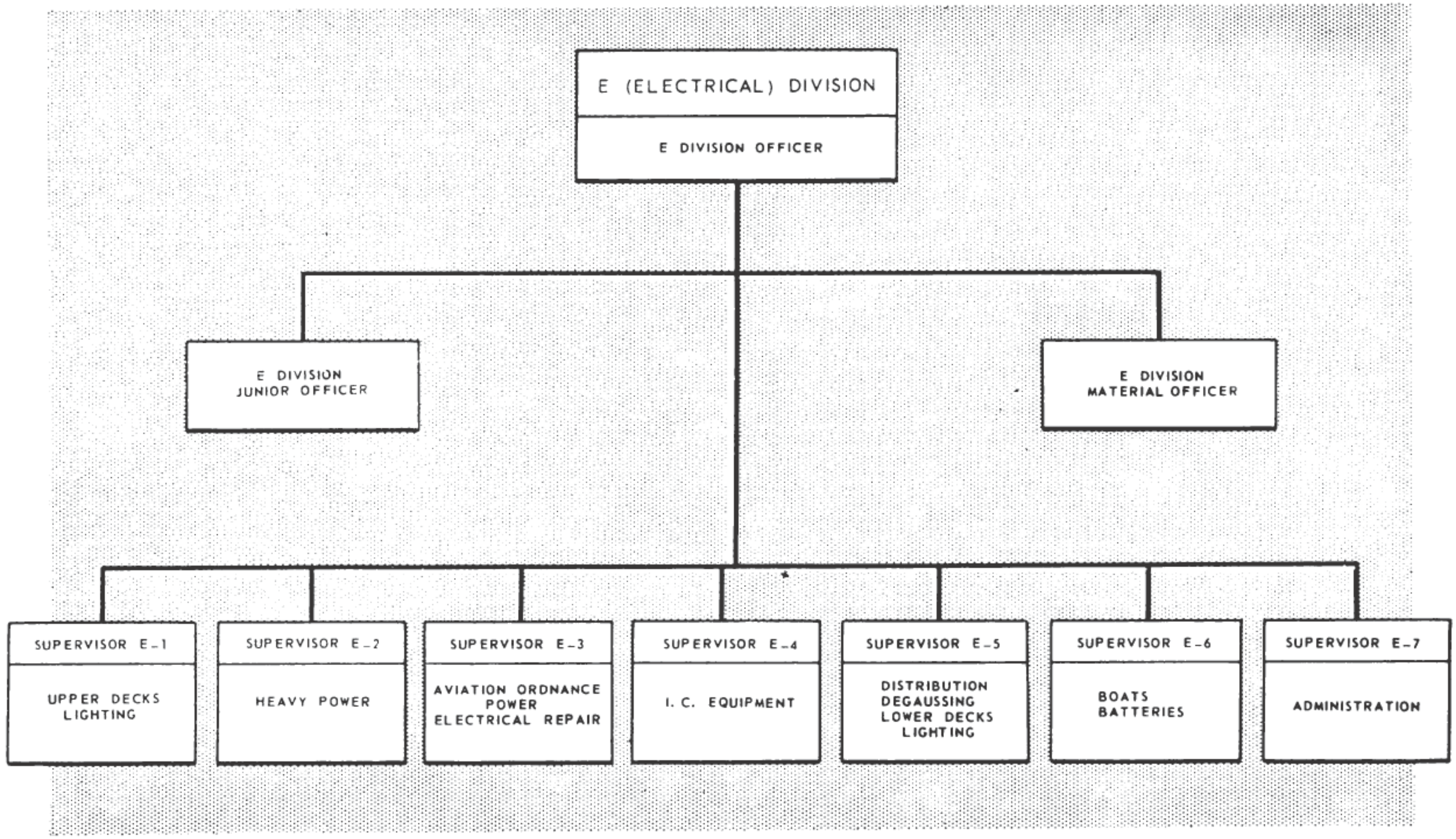


Figure 1—2.—Organization of Electrical Division.

I. C. Group

The I. C. Electricians in the Electrical Division are assigned to the I. C. Group, which is under the direct supervision of the leading I. C. Electrician. This I. C. Group (or gang) comprises subgroups that are responsible for the operation, repair, and maintenance of the specific I. C. equipment and circuits included in the respective group. These subgroups may be responsible for (1) the gyro, (2) the dial telephone and announcing systems, (3) the I. C. instruments, (4) the alarm and warning systems, and (5) the movies. Each of these subgroups, depending on the assigned personnel, may include an IC1 (in charge of the gang), IC2, IC3, and a fireman or striker.

For example, one I. C. Electrician, usually an IC2, is in charge of movies. He is responsible for the operation, care, and maintenance of all motion-picture equipment. He obtains current films through exchanges with other ships, and when in port, from the related shore activity. He maintains an up-to-date inventory of films received and exchanged and a complete record of all repairs to motion-picture equipment, including films.

The proper assignment of available personnel for the upkeep of equipment and for other necessary duties is most essential. It is particularly critical if the group is below its allowance of personnel, or if the available I. C. personnel are inexperienced. The leading I. C. Electricians must therefore be ever alert to the qualifications of the onboard I. C. Electricians.

If the group is well staffed, it will be possible and practicable to double up the inexperienced with some of the more experienced men. In this case, the leading I. C. Electrician should be certain that the experienced man is teaching and not using the inexperienced man as a "handy man."

I. C. Electricians should be rotated on equipments about every three months. This practice tends to broaden their

knowledge and perspective and thus keeps them advancing. This procedure is advantageous to the group and the division as a whole because it means that several of the men will always have a good working knowledge of each equipment.

Each man should also be assigned administrative "paper work" commensurate with his rating. When practicable, personnel can also be rotated among the various types of paper work. This practice tends to keep one man from doing all of the paper work and gives the entire group a broader working knowledge of the organizational details.

Petty officers, First Class and Chief, have attained the stage of advancement in which organization and administration are an ever-increasing part of their duties. Their military duties require them to assist the Division Officer both in organizational planning and in the administrative work of the division.

An able administrator always makes his job easier and maintains a happy working relationship because his organization is steady, the work is well planned, and the abilities of the men in the organization are constantly used and improved. This means that the equipment is kept in a much better operating condition, the outage time is less, the records are up-to-date, and confidence is strengthened in both the organization and in the leader.

Within the I. C. Group there are many specialized jobs to be performed. These jobs can be classified as PRIMARY or SECONDARY. Within the SPECIALTY duties of an I. C. Electrician, the primary duty is to keep the equipment at top performance levels; this means maintenance. The secondary duties, involving records and replacement parts, are also related to maintenance. The secondary duties are very important because records can form a blueprint of recurrent faults in an equipment and will thus lead to more effective maintenance procedures. Also, it would be very difficult to keep equipment in

proper operation without maintaining sufficient and correct replacement parts in stock.

SPECIALTY REQUIREMENTS.—The specialty requirements for IC1 and ICC are outlined in appendix II in the form of qualifications for advancement in rating. These requirements are also published in the *Manual of Qualifications in Rating,* NavPers 18068 (revised). Appendix II should be checked with NavPers 18068 to determine if changes have been made in the qualifications since the publication of this training course.

MILITARY REQUIREMENTS.—The military requirements of a leading I. C. Electrician involve not only his most important function, which is that of leading in time of battle and other emergency conditions, but also his everyday concern with training, health, cleanliness, organization, and liberty of subordinates. He should be as much concerned with the welfare of the personnel of his group as with the maintenance of equipment, for a happy group means top performance of men, and top performance of the men means top performance of the equipment. Top performance of equipment means not only a respected group but also a respected division.

A knowledge of the contents of the *General Training Course for Petty Officers,* NavPers 10055, is essential to understanding military duties. This publication (as well as NavPers 18068) lists the military requirements for advancement for all pay grades.

Duties and Responsibilities

ELECTRICAL OFFICER.—The E (Electrical) Division is headed by the Electrical Officer, who is responsible, under the Engineer Officer, for the organization, administration, and operation of his division and its assigned personnel and material in support of the over-all mission of the ship. He is responsible for the operation, maintenance, and repair of the electrical machinery and systems throughout the ship, except those assigned to another department.

The Electrical Officer in performing his duties shall:

1. Ensure the effective operation of the electrical power, distribution, lighting, interior communications, and degaussing systems, and their associated electrical equipment.
2. Establish and maintain operating routine, observing the performance of personnel and equipment to ensure conformance and efficiency.
3. Act as Division Officer in the administration of the E Division.
4. Ensure the frequent examination of equipment and systems for which he is responsible and supervise necessary repairs or adjustments.
5. Take charge of the electrical plant during General Quarters.
6. Supervise the preparation and care of the electrical sections of the master CSMP (current ships maintenance project) and material history records, and other necessary or prescribed electrical records; verify their accuracy and ensure that they are properly kept.
7. Determine causes of malfunctioning or breakdown of electrical equipment and develop therefrom improved operating and maintenance procedures for approval by the Engineer Officer.
8. Control the expenditure of funds by the E Division within budgetary limitations and procedures established by the Engineer Officer.
9. Perform such other duties as may be assigned.

MATERIAL OFFICER.—The Material Officer, when assigned to a division is responsible, under the Electrical Officer, for the readiness of all assigned electrical equipment and the administration of the electrical material maintenance program.

The Material Officer in performing his duties shall:

1. Formulate and maintain standards and procedures for the operation, maintenance, and repair of the machinery and equipment under the cognizance of

the division; establish and maintain an active CSMP and material history record system.

2. Formulate and utilize methods and procedures for the operation, care, and maintenance of the division equipment within the framework of the Engineering Department and division organization and instructions.
3. Supervise division shops and storerooms; formulate and maintain shop operating procedures.
4. Supervise the personnel of the division in the operation, maintenance, and repair of division equipment.
5. Act as technical assistant to the Division Officer and the Engineer Officer.
6. Act as Division Officer in the absence of the Division Officer and the Junior Division Officer.
7. Examine equipment-operating logs periodically to ensure proper operating procedures.
8. Inspect, in accordance with the *Bureau of Ship's Manual,* the equipment for which the division is responsible and recommend to the Division Officer maintenance schedules and repairs as necessary.
9. Supervise machinery repairs, overhauls, and alterations, and inspect work after completion; maintain a progress chart of all work under his cognizance during shipyard overhaul.
10. Prepare or review prescribed material records and reports, such as CSMP, material history, and material analysis data sheets.
11. Act as custodian of equipage assigned to the division.
12. Investigate causes of equipment failures and casualties; recommend remedial procedures.
13. Requisition material and supplies; initiate requisitions for replacement of parts as necessary within the division budget; and ensure that the Supply Department is informed of spare parts needed and

provide technical assistance to the Supply Department in maintaining a full allowance of spare parts onboard.

14. Perform such other duties as may be assigned.

I. C. ELECTRICIAN, CHIEF.—The ICC shall act as assistant to the division Material Officer, and in performing his duties shall:

1. Directly supervise the corrective maintenance of all I. C. equipment.
2. Instruct personnel (those responsible for operating specific equipments) in the proper methods of performing preventive maintenance.
3. Ensure that equipment history cards, field changes record cards, repair record cards, resistance test record cards, alteration record cards, performance standard books, and maintenance checkoff books are up-to-date.
4. Ensure that complete stocks of all maintenance repair parts are maintained.
5. Be responsible to the division Material Officer for all test equipment and accessories, and for their proper working condition.
6. Prepare the required monthly reports.
7. Supervise the cleanliness and upkeep program for all assigned I. C. spaces.
8. Supervise the preparation of the equipment inventory for the division Material Officer.
9. Maintain the file of I. C. equipment repair service reports and ensure that all sections of these reports are completed and signed.
10. "Ensure that electronics failure reports (Form DD787) are submitted for all failures."

I. C. ELECTRICIAN, FIRST CLASS.—The IC1 in performing his duties shall:

1. Be responsible for the corrective maintenance of all I. C. equipment and circuits included in the respective I. C. Subgroup.

2. Be responsible at all times for the proper operating conditions of all equipment under his cognizance.
3. Ensure that I. C. Electricians in his subgroup are performing their duties of preventive maintenance properly and efficiently; and keep accurate records of such maintenance.
4. Be an assistant and understudy to the ICC and be prepared to double for him at a moment's notice.

SUPERVISION AND LEADERSHIP

The I.C. Electrician, First Class or Chief, needs more than technical skills. He is expected to assume greater responsibility, not only for his own work but also for that of other I.C. Electricians and strikers that serve under him. Briefly, he is required to perform the composite role of master technician, leader, supervisor, inspector, and instructor. The administrative abilities and qualities of leadership acquired by the IC1 or ICC increase his value to the fleet.

Routine and Discipline

The basic function of a leader is to organize the activities of the group members toward the accomplishment of a given task. The duties and responsibilities of each member are spelled out in detail within a good organization. Each man knows exactly what is expected of him. However, the leading IC knows from past experience that the mere listing of duties does not necessarily get them accomplished. The established routine of work activity must be reinforced by discipline. The leading IC's problems of supervision and maintenance of discipline are complicated because in this category he is dealing with human beings and not the inanimate mechanical or electrical components of a piece of equipment. This means that he must supervise in a calm and understanding manner to get prompt and willing compliance with orders. He will command more respect and get better results

by being reasonable and fair. Fairness is not to be confused with laxity or undue leniency.

The repair of I.C. equipment requires the utmost in concentration. For this reason, the men will need periods of relaxation. These periods should be considered in preparing estimated man-hour schedules. If the factor of fatigue is not taken into consideration, work will fall behind schedule. On the other hand, if the supervisor grants an excessive number of breaks, he may lose control over the group. He must strive for a happy medium in each situation, and be flexible enough to allow for changing conditions. There are times when an all-out effort must be made to complete repairs in the least possible time. Under these circumstances the maximum effort is demanded of everyone.

The standards of conduct that are established in each situation should be uniform for all concerned. Favoritism should never be shown. The attitude should be impartial, consistent, and humane in giving praise or censure.

Praise and Censure

There is a common misconception that discipline is merely a matter of administering censure or punishment. Discipline also has its positive aspects that are too often overlooked. When the leading IC inspects the work of a subordinate, he should resist the tendency to comment only on the mistakes that are made. Favorable comments on the good part of the job should be made at appropriate times. It is true that no one is entitled to extra medals for doing a job well because that is his job. Nevertheless, a kind word goes a long way in boosting morale. However, excessive flattery should be avoided.

The leading IC should avoid being a "credit grabber." When praise is received, it should be passed down the line to his subordinates who helped earn the commendation. Recognition given to his men for a job well done is music to their ears. Another good rule to remember is "praise in public, censure in private." One must be certain that

a man understands WHY he is being censured, and one should be especially careful to avoid the use of sarcasm.

Because praise and censure may work both ways, it is necessary to establish the proper relationship between the men and their leader.

The Men and Their Leader

True discipline is obtained through the voluntary cooperation of the men with their leader. It should be recognized that cooperation is a two-way proposition. The men depend on the leader to fulfill many of their psychological needs. They look to the leader for the security of his approval. They WANT a supervisor whom they can respect and brag about. By the same token, the leading IC wants a crew that will be a credit to him, to the ship, and to the fleet. It takes hard work on the part of both to earn this mutual respect. The relationship that the leader establishes with his men is a reflection of his attitude toward them. If he knows and understands them, has respect for their dignity as human beings, and shows a sincere interest in their welfare, they will respond with renewed energy and with pride and confidence in his leadership. They will work because they WANT to and not because they are compelled to or because they fear punishment. This is what is meant by voluntary discipline. It is based on knowledge, reason, sense of duty, and loyalty, and is closely related to morale or esprit de corps.

A leader should learn all he can about each member of his crew (their names, ambitions, problems, capabilities, and limitations). The men should know that he is sincerely interested in their welfare. The leader should be careful, however, not to carry this to extremes and perform the duties of the chaplain. It is a good rule not to volunteer advice on personal problems. However, a man with such problems often needs someone whom he respects to talk to so that he can get the problem "off his

chest." By simply being an understanding listener, it is possible to be of great help in such circumstances.

At the same time, the men should be given an opportunity to get to know the leader. In this way a common ground of understanding is established. When work is to be done, the leader should be in the area. His presence indicates that he knows what is going on and is interested in what the men are doing. This does not mean that he has to stand over them, breathing down their necks at all times. He should be available for consultation, and he should keep himself informed on the progress of the work. Except in emergencies, he should tell the men what to do rather than how to do it. In this way they will learn by doing. When his advice is needed, he will know the weak points of his men and can utilize this opportunity to advantage for on-the-job training.

The leading IC should be a good craftsman, and his skill must be reflected in the high quality of his own workmanship. In fact, his work should set the example for others to imitate. He should know his job and keep abreast of new developments that may affect his work. The maintenance of discipline becomes vastly easier if the leader is proficient in his technical specialty.

It should be borne in mind, however, that no one person knows all the answers. If a leading IC is confronted with a question he cannot answer, he should admit it and not try to bluff. An attempted bluff is too great a gamble because he will lose the respect of his men if it does not work. Instead, every effort should be made to find the answer to the question. When the answer is found, it should be shared with the man.

This leads to another important requirement of good supervision, which is that of keeping all hands informed of what is going on.

Keeping All Hands Informed

Posting notices does not ensure that everyone will get the word. Personal attention to getting the word ex-

plained to every man will pay big dividends in building an alert, smooth-running organization. Thus far, mention has been made only of passing the word DOWN through the organization. Passing the word UPWARD is just as important. The leading IC is the link in the chain of command between his men and the division Material Officer. He should always be alert to get the reactions of his men. Very often a small, petty gripe will be gnawing away at the men and wreak havoc with morale. Unless the leader is aware of the gripe, he is in no position to do anything about it. Of course, the leader cannot work miracles because there are some things about which he will be unable to do anything. Promises that cannot be kept should not be made. Giving the crew a chance to get a gripe off their chests by discussing it calmly with the leader will help clear the air and keep the men from working at cross purposes.

A necessary adjunct to passing the word, or the transfer of ideas and information, is the establishment of the right kind of human relations.

Human Relations

Human relations can be defined as the art of getting along with people. Unfortunately, there are no magic rules of conduct or "bag of tricks" that will guarantee a person success in getting along with everyone. There are, however, several character traits such as dependability, punctuality, consideration, and tact that can be developed to make the job of supervisor easier. Dependability means reliability or trustworthiness. Punctuality means promptness—getting where you are supposed to be on time. Consideration is the thoughtful regard and respect for the needs and feelings of others. Tact is presenting the truth with consideration; it is the knack of saying the right thing at the right time without giving offense. It may be difficult to be tactful at times, especially when the situation is urgent and tempers have been aroused. One of the keys to good human relations is the

technique of giving the other fellow a chance to get out of the argument gracefully.

There are other things that one can do to help him get along better with people. He should learn to smile in a sincere, warm and friendly manner; he should become genuinely interested in other people. Likewise, he should try to make the other person feel a sense of personal importance. The problem of leadership and successful human relations is not so much a question of knowing a long list of specific techniques as it is a question of knowing WHEN to employ each technique. This is usually a matter of using common sense.

Getting along with people is a knack that can be acquired; but, as with learning any other skill, it takes practice. Actually, to a large extent, it merely involves being sufficiently alert and intelligent to put oneself in the other fellow's place. Many pointers are contained in the *General Training Course for Petty Officers,* NavPers 10055, but unless these pointers are put into practice, even in trivial matters, the mere reading of the book will be a waste of time. Nothing succeeds like success. If a leading IC makes a practice of handling effectively all of the minor problems in his daily work, he will find that he will be confronted with fewer major problems. Moreover, those that do arise will be easier to solve because of his previous successful experiences in handling the smaller problems.

In his daily work the leading IC will be dealing with operating personnel, with the Supply Department, and others. He should make it a point to understand how the duties of the other ratings affect his work and exactly what and how much can be done by each. Thus, a common language will be established and time and tempers will be saved. Good relations and close cooperation between the divisions are essential to their individual and collective functioning and make for a tightly knit ship's organization. While it is a natural and healthy sign

afloat and ashore that good-natured rivalry usually exists between the various organizations, it must be remembered that each organization depends on the others for certain phases of work. It is one of the many duties of the leading IC to promote good will and teamwork between the various organizations.

TRAINING

The best ships and equipment are of little use without trained personnel. The operational readiness of every unit in the Navy depends, in a large measure, on the knowledge and skill of every crew member. The Navy, therefore, places great emphasis on training and recognizes the need for supplementing the formalized instruction of the service schools with on-the-job shipboard or shore-based training.

Training Plan

Training is a function of all commands. The Navy relies heavily on the First Class and Chief to teach technical skills in practical on-the-job situations. In fact, the supervision and training of other IC's is listed as one of the qualifications for advancement in rating for the ICC.

When the IC1 or ICC reports aboard for duty at a new ship or station, he is likely to find the training schedule already set up and in effect. However, he should be able, under the supervision of his Division Officer, to plan, administer, and coordinate the training of personnel in the I.C. Group. The qualifications for advancement in rating listed in appendix II will be of help in developing a training plan for the crew.

Planned instructions mean that the men will be instructed in an orderly step-by-step fashion. Because the instructor is dealing with individuals who possess varying degrees of skill and training, the problem is more complicated than if all of the men were beginning on the same level. First, the instructor will have to keep himself constantly informed on the individual training status of each

man and plan his long-range program accordingly. Second, the different degrees of capability make it necessary for the instructor to individualize his instructions as much as possible. Although it will take more time, this arrangement has obvious advantages. There will be times when, under the pressure of a heavy maintenance workload, scheduled instruction will have to be temporarily suspended. If at all possible, time lost in this way should be made up later. Written records of the instruction time table should be kept. Like the daily work sheet, the training program will have to be carefully prepared in advance. Common sense will dictate that it should be flexible and adaptable to changing conditions.

A training plan is without practical value unless it includes provision for the proper type of instructor.

The Instructor

To become an effective instructor, the IC must acquire many of the same qualities possessed by a good leader. The technical ability, personality, enthusiasm, sense of humor, sense of responsibility, ingenuity, and military bearing of the instructor will all enter into the picture. The list of desirable characteristics of a good instructor is endless because the circumstances under which instruction is given vary as much as do the capabilities of the men. The instructor may have to be hard-boiled with one man, especially patient with another, while a third may require a high degree of tact. In any case, the instructor should be sufficiently flexible to adapt himself and his methods to the requirements of the man, the subject matter, and the situation. It must be remembered that this is, for the most part, on-the-job training, not formal classroom work.

The instructor is responsible for the man's training as long as he is a member of the group. The trainee must be motivated to learn. His interests and desires must be aroused so that he will be willing to learn. At the same time, he should be made conscious of the practical use of

the subject or skill he is expected to learn. First impressions are lasting ones. Therefore, the new subject must be presented correctly the first time. This is especially true of interior communications. Finally, the trainee should experience a feeling of satisfaction after having made the effort to learn.

A good instructor makes use of various methods of training.

Methods of Training

The many different methods of training include lectures, discussions, demonstrations, pupil-coaching, laboratory work, and actual maintenance. Additional pointers on techniques are published in the *Manual for Navy Instructors,* NavPers 16103–B and in the *General Training Course for Petty Officers,* NavPers 10055. Formal training (lectures and discussions) teaches the men the theory and principles of I. C. equipment maintenance. Demonstrations show the men the right way to perform a job. These are not sufficient because telling is not always teaching, observing is not always understanding, and listening is not always learning. If a man has the proper background (information acquired through lectures and study), then he learns best by DOING. On-the-job training produces the real skill. Dexterity, precision, and the knack of handling tools are obtained only through work experience.

It is a good idea, therefore, to plan the lesson in advance whenever possible so that full use may be made of the advantages of each method of instruction. The following procedure is suggested:

1. Explain the importance of the job.
2. Show the trainee how to do the job, explaining each step as it is performed. (If this is not possible, do the next best thing; use schematics, mock ups, or other appropriate training aids for presenting a demonstration. Put special emphasis on SAFETY.)

3. Do the job again and have the student explain each step as it is done.
4. Allow the trainee to do the job and have him explain each step while he performs it.
5. Point out errors, and ways to improve his work.

The Navy is fully behind the instructors and the instruction program, and has accumulated an assortment of training aids obtainable through the education officer.

Listings of films and film strips may be found in the *United States Navy Film Catalog,* NavPers 10,000 and the latest supplements thereto.

Unfortunately, even an experienced, intelligent, and capable technician is not always a good instructor. There are many techniques that may be employed by a good instructor in presenting the material, but there are no substitutes for (1) knowing the subject matter thoroughly, and (2) being well prepared to give instructions.

It can be readily seen that if an instructor does not know the subject matter thoroughly he will not be able to present the instruction properly, answer questions readily, or retain the attention and confidence of his students.

If the instructor is not well prepared, he will fumble throughout the presentation, fail to present the facts in a logical learning sequence, fail to have all the necessary instructional aids at hand, and thereby lose the attention and confidence of his students.

The Navy has many good instructor-training films, which should be shown periodically to the entire division. Some of these have already been listed.

The Training Schedule

A continuing program of training is vital and necessary to make the technicians more proficient in their duties and eligible for advancement. From 1 to 2 hours each day should be set aside for the training program. This program need not always be formal. It can be a group discussion of different phases of equipment or duties.

For the formal type of instruction, a subject should be

selected that is essential to the progress of all attending personnel. In this type of instruction, it may be necessary to separate the trainees into small groups in order to standardize the level of the material presented.

An excellent program of training is to have each tech-

INDIVIDUAL TRAINING RECORD

NAME ROTH, A.J. RATE/RANK IC 2 CLASS USN SERVICE NO. 376-62-54

DIV E SEC 1 NJC IC-4722 TOTAL NAVAL SERVICE 3 YEARS - 10 MOS.

TIME IN PRESENT RATING 1 YEAR EXPIRATION OF ENLISTMENT JUNE 15, 1957

EDUCATION: PUBLIC SCHOOL ____ YEARS 12 COLLEGE NONE YEARS NONE

USAFI COURSES NONE LEVEL NONE CREDITS NONE

JOBS HELD GYRO REPAIR, AUTOMATIC TELEPHONE ELECT.

FOREIGN LANGUAGE QUALIFICATION:

	SPEAK	READ	WRITE
GERMAN	✓	✓	✓

NAVAL EXPERIENCE:

SCHOOL ATTENDED IC "A" LENGTH 14 WKS. LOCATION SAN DIEGO, CAL.
DATE COMPLETED JAN. 15, 1954

SCHOOL ATTENDED GYRO LENGTH 12 WKS. LOCATION WASH. D.C.
DATE COMPLETED JUNE 10, 1956

SCHOOL ATTENDED ______ LENGTH ______ LOCATION ______
DATE COMPLETED ______

TRAINING COURSE COMPLETED IC 3 & 2 DATE JAN. 15, 1954

TRAINING COURSE COMPLETED IC 1 DATE OCT. 20, 1956

PREVIOUS DUTY

SHIP TYPE CL TIME ON BOARD 13 MO. STATION ______ TIME ______
SHIP TYPE AD TIME ON BOARD 18 MO. STATION ______ TIME ______
SHIP TYPE ____ TIME ON BOARD ______ STATION ______ TIME ______

JOB: SPECIAL OR UNUSUAL DUTY PERFORMED QUALIFIED GYRO REPAIRMAN

SPECIAL ACHIEVEMENT OR RECOGNITION (CIVILIAN OR SERVICE) NONE

PREVIOUS MILITARY SERVICE OTHER THAN NAVAL 1 YEAR NATIONAL GUARD

DUTY PREFERENCE ABOARD ______

ADDITIONAL INFORMATION ATTENDED BELL TELEPHONE Co. SCHOOL. AUTOMATIC TELEPHONE - QUAL. TO MAINT, REPAIR, SWITCHBOARDS, POWER EQUIP. & CIRCUITS ON AUTOMATIC TELEPHONES.

Figure 1—3.—Individual training record.

nician give a series of lessons on the equipment that he maintains. He can point out the characteristics and special troubles that may be peculiar to certain of his equipments. This type of program gives the entire division general information and some working knowledge of each equipment aboard.

For the best possible administrative control of training, a standard-form record for each man should be maintained in duplicate. One copy of this record should be kept in the division training records, and the second should be placed in the man's personnel record when he departs from the ship or station for duty elsewhere.

A form that may be used to record the over-all training performance of a technician while he is attached to a command is illustrated in figure 1–3. Equipments may also be listed on this type of form to show the practical experience gained.

Training Bill

A training bill that can be adapted for use on almost any type of ship is shown below.

I. GENERAL

The ever-present need for raising the operating efficiency of individuals and teams to the highest possible standard requires the constant application of the energies and resources of every officer and man aboard, each in the dual capacity of trainer and trainee, to the accomplishment of an adequate training program.

II. OBJECTIVES

A. Develop maximum battle and operational efficiency by:

1. Imparting to all IC's the technical knowledge and skill needed for the operation, maintenance, and repair of the ship's I. C. equipment.

2. Raising the efficiency of individuals through improvement of their military and professional qualifications and by the development of high morale.

B. Prepare each officer and enlisted man for greater command by training in:

1. Execution of all duties of present position in the ship or division organization.

2. Preparation for duties of next higher position in the organization.

3. General subjects, designed to broaden his knowledge of naval operating procedures.

III. PERSONNEL ORGANIZATION

A. The training duties and responsibilities of the division Material Officer—under the general supervision of the Electrical Officer, the division Material Officer shall:

1. Determine the E Division training needs within the scope of the ship's training objectives.

2. Administer a training program that will meet the needs of the division.

3. Supervise the training of all commissioned officers and petty officers who are to be instructors.

4. Organize and direct a suitable orientation program for new hands.

5. Observe and evaluate the quality of instruction given.

6. Keep suitable records.

7. Prepare and arrange course material for presentation.

8. Assemble, catalogue, and make available all training information, aids, courses, and similar material.

B. Duties of other commissioned officers and petty officers—each shall:

1. By his enthusiastic participation in the training program, set an example for others in order that they will be motivated to take complete advantage of the opportunities for training that are offered.

2. Constantly strive to perfect his skill in technical matters as well as in instructional methods.

IV. HOW TRAINING IS TO BE CONDUCTED

A. On-the-job training—primary emphasis shall be on training personnel to perform the duties assigned them as individuals, crews, parties, or teams. Instruction in these duties shall take place during watches, drills, and evolutions (naval exercises). Everyone shall be responsible for training his subordinates at these times and shall take advantage of every opportunity to train them in the functions that they must perform.

B. Classroom instruction—while all skills and some of the related information may best be taught on the job, certain basic information may best be taught by group-instruction methods. These subjects shall be scheduled for off-duty periods, but shall not be substituted for practical instruction.

C. Schools—maximum utilization shall be made of shore-based schools, consistent with the needs of the ship.

D. Individual study—the study of applicable subjects and equipment by the trainee during his leisure time must be encouraged.

V. TYPES OF TRAINING

A. Orientation

1. Each new man coming aboard shall be given instructions immediately in those topics that will lead to his rapid assimilation into the division.

2. Periodically, emphasis will be placed on the necessity for complete knowledge of individual jobs and the need for teamwork.

B. Individual training—each man shall be encouraged and given the opportunity to do individual study in subjects that will advance him academically, vocationally, and avocationally. Navy correspondence courses, USAFI courses, advancement in rating courses, and other similar courses are examples.

C. Group training—team drills and formal instructions shall be planned, organized, and conducted in technical and operational duties in such a manner that instruction is as practical as possible, and is used to its maximum advantage.

VI. PATTERN OF TRAINING

A. Petty officers presently aboard shall be trained as instructors. This training shall be based on the information contained in the *Shipboard Training Manual,* NavPers 90110.

B. Petty officers reporting aboard shall be indoctrinated in the ship and division regulations and trained as instructors. This training shall also be based on the information contained in the *Shipboard Training Manual,* NavPers 90110.

C. Strikers, following orientation and indoctrination, shall be assigned to petty officers and individual on-the-job instruction purposes and rotated in such a manner as to become most effective in the performance of their duties.

VII. TRAINING PLANS AND RECORDS

A. Lesson plans (fig. 1–4) shall be prepared for every unit of instruction.

B. Training records

1. Progress charts (fig. 1–5) shall be prepared by the petty officer in charge, and shall list the personnel involved in the training program and the subjects covered.

2. Individual training records (fig. 1-3) shall be maintained for each trainee.

Signed: ______________________

Approved: ______________________

Electrical Officer — Division Material Officer

LESSON PLAN FORM

LESSON NO: 4

LENGTH: 1 hour

TITLE: Finder board, function of

OBJECTIVES: To impart knowledge about automatic ships service telephone switchboard
To develop skill in maintenance of this equipment

MATERIALS: (a) References: (if any) NavShips 365-0181, Ship's Service Telephone System - Automatic Type

(b) Training Aids: Ship's Service Automatic Telephone Switchboard

INTRODUCTION: Explain and demonstrate basic principles of operation of the finder board

PRESENTATION: Finder board
a. Functions
1. Finding the calling line
2. Calls to a station
3. Connection to a shoreline circuit
4. Executive right-of-way service
5. Start and level marking circuit
6. All finders busy
7. Line disconnect key circuit
8. Simultaneous calls
9. Finder blocked key circuit

APPLICATION: Work on job
Work on project set up in I.C. room

SUMMARY: Strengthen weak spots of lecture and demonstration by answering all questions
Each trainee to give practical demonstration and explain

ANNEX (1)

Figure 1—4.—Lesson plan form.

U. S. S. *Manchester (CL-83)*

INTERIOR COMMUNICATIONS

CHECKOFF BLOCKS SHOULD SHOW DATE TRAINEE QUALIFIES AND INITIAL OF INSTRUCTOR

NO.	NAME	RATE	SHIPBOARD ORIENTATION	DEPARTMENTAL ORIENTATION	SAFETY PRECAUTIONS	ARTIFICIAL RESPIRATION	I. C. RECORDS	I. C. REPORTS	I. C. PUBLICATIONS	PREVENTIVE MAINTENANCE	PREVENTIVE—MAINTENANCE CHECKOFF LISTS	I. C. EQUIPMENT PERFORMANCE	CORRECTIVE MAINTENANCE	I. C. EQUIPMENT FAMILIARIZATION	TECHNICS OF INSTRUCTION NAVPERS 90110-1	TRAINING ADMINISTRATION NAVPERS 50110	SHIPBOARD PROCEDURE FOR REQUISITIONING SPARES AND STORES	GENERAL TRAINING COURSE FOR PETTY OFFICERS PART I	GENERAL TRAINING COURSE FOR PETTY OFFICERS PART II	TECHNIQUES OF KEEPING MAINTENANCE PARTS INVENTORY	ADVANCEMENT IN RATE TRAINING COURSE
1	Halpern, M.A.	IC1	R.J.M. 2-4-57	R.J.M. 2-4-57	R.J.M. 2-6-57	R.J.M. 2-6-57	R.J.M. 3-1-57	R.J.M. 3-1-57	R.J.M. 3-1-57	R.J.M. 4-10-57	R.J.M. 12-1-56	B.B.B. 12-1-56	B.B.B. 12-1-56	B.B.B. 12-15-56	B.B.B. 1-1-57	B.B.B. 1-10-57	B.B.B. 2-10-57	B.B.B. 2-15-57	B.B.B. 2-20-57	B.B.B. 12-7-56	B.B.B. 6-1-57
2	Dollander, M.M.	IC1	R.J.M. 3-1-56	R.J.M. 3-10-56	R.J.M. 3-10-56	R.J.M. 3-10-56	R.J.M. 3-10-56	R.J.M. 3-10-56	R.J.M. 5-2-56	R.J.M. 5-2-56	R.J.M. 5-2-56	R.J.M. 9-20-56	R.J.M. 9-20-56	R.J.M. 9-20-56	R.J.M. 9-20-56	R.J.M. 9-20-56	R.J.M. 9-20-56	R.J.M. 10-20-56	R.J.M. 10-20-56	R.J.M. 10-20-56	B.B.B. 10-20-56
3	Paffenberger, M.J.	IC2	R.J.M. 4-4-56	R.J.M. 4-8-56								R.J.M. 6-6-56									
4	Benson, H.W.	IC2	R.J.M. 6-1-55	R.J.M. 6-7-55								R.J.M. 8-1-55									
5	Hopkins, A.P.	IC3	B.B.B. 7-3-57	B.B.B. 7-10-57								B.B.B. 9-1-57									
6	Eckberg, A.T.	IC3	B.B.B. 7-3-57	B.B.B. 7-10-57								B.B.B. 9-1-57									
7	Kuykendahl, T.B.	IC3	B.B.B. 7-3-57	B.B.B. 7-10-57								B.B.B. 9-1-57									
8	Bennett, H.M.	ICFN	B.B.B. 7-3-57	B.B.B. 7-10-57								B.B.B. 9-1-57									

Figure 1—5.—Progress chart.

QUIZ

1. Name the two basic aspects of shipboard organization and their relationship with each other.
2. Name the three organization structures that represent the mechanical aspects of shipboard organization.
3. What means are used to present graphically the arrangement of the departments, divisions, and billets for the line and staff relationships of all personnel within the ship's organization?
4. The assignment of personnel through what specific bill represents the so-called dynamic aspect of shipboard organization?
5. What is another name for the functional guides used to present the broad objectives of a specific billet?
6. Name the publication that is the basic directive that governs the internal administrative and watch organization of the ship.
7. What is the primary purpose of the *Ship's Organization and Regulations Manual*?
8. What type of information is included in the Department and Division Organization Manuals used to supplement the *Ship's Organization and Regulations Manual*?
9. What are the two primary purposes of the Department and Division Organization Manuals?
10. Give an example of how the material included in the Department and Division Organization Manuals may vary from that for a large department to that for a small department.
11. How is the assignment to duty in a Ship's Organization Bill normally indicated in the Watch, Quarter, and Station Bill (fig. 1–1)?
12. Through what publication is the Personnel Allocation List promulgated to the ship's company?
13. The complement of a combat ship is based on the number of personnel required to perform what three general types of duty?
14. How is the allowance of a combat ship related to the complement necessary to maintain and operate the ship under peacetime conditions?
15. The allowance of a combat ship is a flexible component in personnel administration based on what two high-level factors?
16. (a) Into how many approximately equal sections are the personnel of each division of a combat ship divided for wartime

organization? (b) What are the general requirements of each section?

17. Name two primary considerations in the assignment of personnel in the organization structure of a ship.
18. What are the general responsibilities of the I. C. Subgroups as related to their assigned I. C. equipments?
19. Why should IC's be rotated on equipments about every three months?
20. What should be the policy with regard to the assignment of "paper work" to IC's?
21. Name the (a) primary and (b) secondary duties within the specialty duties of an IC.
22. What is the Electrical Officer responsible for?
23. What is the Material Officer responsible for?
24. What is the basic function of a leader?
25. Is discipline merely a matter of administering censure or punishment?
26. How is true discipline obtained?
27. What is the definition of "human relations?"
28. Name four character traits that can be developed to make the job of supervisor easier.
29. Why does the Navy place great emphasis on training?
30. Name seven desirable characteristics of a good on-the-job training instructor.
31. Name six different methods of training.
32. How does on-the-job training produce the real skill?
33. State briefly the five steps for a good training lesson presentation.
34. Name the two requisites of a good instructor.
35. Approximately how much time should be allotted each day for the training program?
36. What type of training program provides the entire division with general information and some working knowledge of each equipment aboard ship?
37. What is the best method of administrative control of training?
38. Name the two types of records that should be included in a good training bill.

CHAPTER 2

GAS-FILLED ELECTRON TUBES

The high-vacuum tube and the gas-filled tube are the two basic types of electron tubes. The HIGH-VACUUM TUBE is characterized by (1) high vacuum inside the envelope, (2) large peak inverse voltage rating, and (3) low efficiency. This tube is particularly suited to communications systems in which the amplified signal must be accurately reproduced and the power requirements are low.

The GAS-FILLED TUBE, on the other hand, is characterized by (1) low pressure of an inert gas in the envelope, (2) low peak inverse voltages, and (3) high efficiency of energy transfer. This tube is well suited to heavy-duty service in which the tube must handle sudden high-current demands, such as those required in the control of various servomechanisms and in gyrocompass follow-up systems.

CHARACTERISTICS OF GAS TUBES

High-vacuum rectifier tubes are capable of delivering high voltages to the loads in electronic circuits, but the peak rates of current flow through these tubes are usually less than 1 ampere. The power required to force electrons through a tube depends on the amount of current and the magnitude of the voltage applied between the plate and cathode. The internal effective resistance of the tube depends upon the space charge, the internal spacing between the plate and cathode, and the size of these

elements. Under normal operation the space charge is constant and the tube characteristics do not change; hence the effective resistance is constant. Therefore, the voltage drop across the high-vacuum tube increases directly with the tube current.

Most high-vacuum rectifier tubes require from 200 to 300 volts for every 0.1 ampere of current flow. This voltage drop across the tube represents a loss because it never reaches the load. The loss of voltage and power is not serious in high-vacuum rectifier tubes in which the rates of current flow are usually between 30 and 250 milliamperes. However, with higher rates of current flow these voltage drops and energy losses become a decided disadvantage. The disadvantage of such losses is overcome by introducing a small amount of inert gas into the envelope after the air has been evacuated. Argon, neon, nitrogen, xenon, or mercury vapor are generally used for this purpose.

Conduction in Gas Tubes

A gas-filled tube contains millions of gas molecules. The atoms that comprise these molecules are electrically neutral, each containing balanced quantities of protons and neutrons in the nucleus, surrounded by an equal number of electrons in the outer orbit. In a hot-cathode gas diode, for example, the high-velocity electron stream travels from the cathode and encounters atoms on its way to the plate. When an electron collides with an atom of gas the energy transmitted by the collision may cause the atom to release an electron. This second electron may then join the original stream of electrons and thus be capable of liberating other electrons by similar collisions. The atom that has lost an electron now has a positive charge and is known as an ION. The process of producing ions in a gas or vapor is called IONIZATION.

The tube in its ionized condition contains gas molecules, ions, and free electrons, within the envelope. The heavier positive ions are attracted toward the negative cathode;

and in the vicinity of the cathode they neutralize the space charge, which results in increased emission current and less opposition to current flow in a gas tube than in a vacuum tube.

The degree of neutralization of the space charge varies with the plate current. The more completely the space charge is neutralized the lower will be the internal resistance of the gas diode. This action maintains the voltage drop through the tube practically constant for all rates of current flow within the tube. From the formula, $E = IR$, it should be noted that as I increases, R decreases, thereby maintaining the product almost constant. A gas tube normally has a voltage drop of from 15 to 25 volts and a mercury-vapor tube has a voltage drop of from 5 to 20 volts.

The energy required to dislodge electrons from their atomic orbits and to produce the ionization is supplied by the source, which supplies the voltage between the plate and cathode. For a particular gas tube there is a certain value of voltage at which ionization begins. When ionization occurs, large currents instantly flow with relatively low voltage drop across the tube. The voltage at which ionization commences is known as the IONIZATION POTENTIAL, STRIKING POTENTIAL, CRITICAL POTENTIAL, FIRING POINT, or BREAKDOWN POINT.

After ionization has started, the voltage drop across the tube is considerably lower than that of the firing point. If the voltage across the tube falls below the minimum value that is required to maintain ionization, the gas deionizes and conduction stops. The voltage at which current ceases to flow is the DEIONIZING POTENTIAL, or EXTINCTION POTENTIAL. Thus the tube can be used as an electronic switch that closes at a certain voltage to permit current to flow and then opens at some lower voltage to block the flow of current. Such a tube has almost infinite resistance before and almost zero resistance after ionization has taken place. A gas tube normally has a higher

plate-current rating than a vacuum tube of the same physical dimensions because of the lower internal resistance caused by the ionization process.

Limitations of Gas Tubes

One limiting disadvantage in the use of gas in an electron tube is the possibility that the tube will permit current to flow in the reverse direction (arcback) when the plate has a high negative (inverse) voltage with respect to the cathode. This peak inverse voltage rating varies inversely with the temperature and pressure of the gas.

A second limitation is the possibility that the cathode may be destroyed by positive-ion bombardment as the plate voltage is increased to a high value. The space charge is reduced and the ions encounter less attractive force as they emerge from the space charge on their way to the cathode. Because of the relatively great mass of the ion, the result of its impact on the cathode may be serious, especially if the cathode is of the oxide-coated type. If the plate voltage is raised to a sufficiently high value, double ionization (two electrons dislodged from the gas molecule) occurs and the resultant increased velocity of the ions may quickly damage the emitter surface. The solution is to keep the plate voltage below the double-ionization potential or to use a more rugged emitter, which unfortunately has a higher work function.

Another limitation at high-operating frequencies is the possibility that arcback will occur because too many ions remain between the plate and cathode on the negative half cycle. This condition results from the fact that at high frequencies there is not sufficient time for the ions to be neutralized by the electrons before the full reverse voltage is applied. Because arcback causes the tube to offer a low resistance on both halves of the cycle, the power dissipated is increased and the tube will probably be destroyed. At high operating frequencies, arcback may occur at a fairly low voltage and hence the tube has a low INVERSE VOLTAGE RATING.

A high-vacuum electron tube may be connected across a source having relatively low resistance because the space charge in the tube limits the current to a safe value. On the other hand, a gas tube cannot be connected directly across a low-resistance circuit without a series limiting resistance because there is no appreciable space-charge effect to limit the current flow, and thus the tube may be destroyed.

GAS DIODES

Several types of gas diodes are shown by the diagrams in figure 2–1. In such diagrams a small dot within the circle always denotes that the tube is gas-filled.

Hot-Cathode Diode

A hot-cathode mercury-vapor diode of the filament heater type (fig. 2–1,A) is specially designed for use as a rectifier. Tubes of this type can pass much higher currents than vacuum tubes because the ionization of the mercury vapor contributes materially to the electron flow by dispelling the cathode space charge. Mercury vapor is formed in these tubes when the small amount of liquid mercury enclosed within the envelope is vaporized by the hot cathode. Sufficient time must be allowed for the

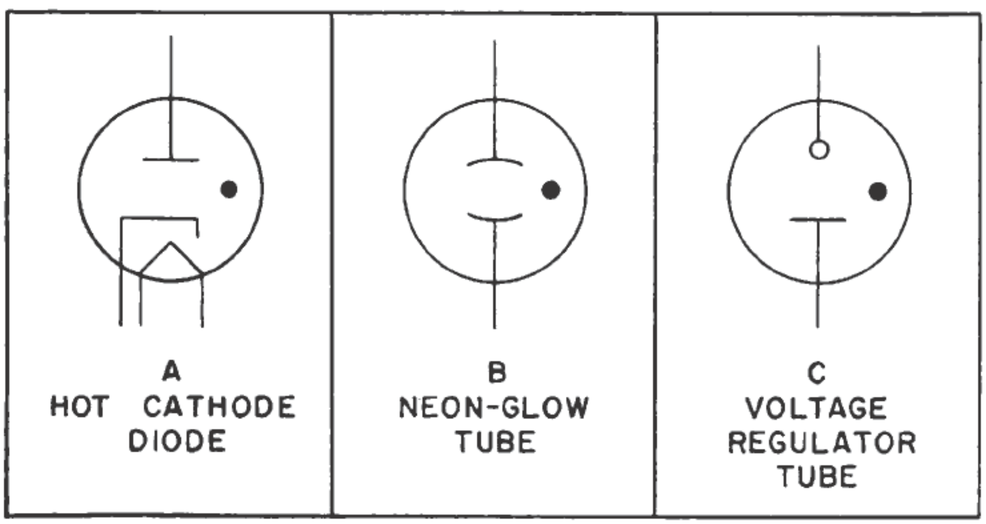


Figure 2—1.—Gas diodes.

cathode to become heated before the plate voltage is applied. If sufficient time is not allowed, the gas will not properly ionize because (1) it will be insufficiently heated to become a vapor, and (2) there will be insufficient cathode electron emission. Cathode electron emission acts as a barrier between the gas ions and the cathode. Consequently there will be excessive voltage drop across the tube and excessive charge on any positive ions, with resulting high velocity towards the cathode. Eventual cathode disintegration by positive ion bombardment will result. When the temperature and pressure are normal, the normal ionization of the mercury vapor dispels the space charge, thus providing normal tube current with characteristic low voltage drop across the tube (about 15 volts for mercury), and the cathode emission protects the cathode from ion bombardment.

Neon-Glow Tube

The neon-glow tube, or neon-glow lamp (fig. 2–1,B), is a cold-cathode gas diode. The cathode may have the same shape and size as the plate so that the tube can conduct in either direction, depending only on the applied potential, or the structure of the cathode and plate may be such as to permit conduction in only one direction (fig. 2–1,C). In this type of tube no electrons are emitted to help in the ionization process because the cathode is not heated. Therefore, the firing potential for a neon-glow tube is higher than that for a tube having a hot cathode. The operation of the neon-glow tube is somewhat erratic because of the variation of the firing potential. Ionization of the gas within the tube is indicated by a glow, the color of which depends upon the gases that are mixed with the neon. The glow surrounds the negative electrode or cathode. When a 60-cycle a-c voltage is applied, both electrodes are alternately surrounded with a glow, thus producing a noticeable flicker as the glow occurs first on one electrode and then the other.

A neon-glow tube is used also as a voltage regulator

(fig. 2–1,C). This application of the tube is described in the training course, *I. C. Electrician 2,* NavPers 10556. Additional uses of glow tubes are as a source of light, as a part of a relaxation oscillator, as a rectifier, and as a control for the circuit continuity in noise limiters.

THYRATRONS

A gas triode or tetrode in which a grid is used to control the firing potential is called a THYRATRON (fig. 2–2). It has a heater type of cathode that consists of a thoriated-tungsten shield enclosing a tungsten filament to protect

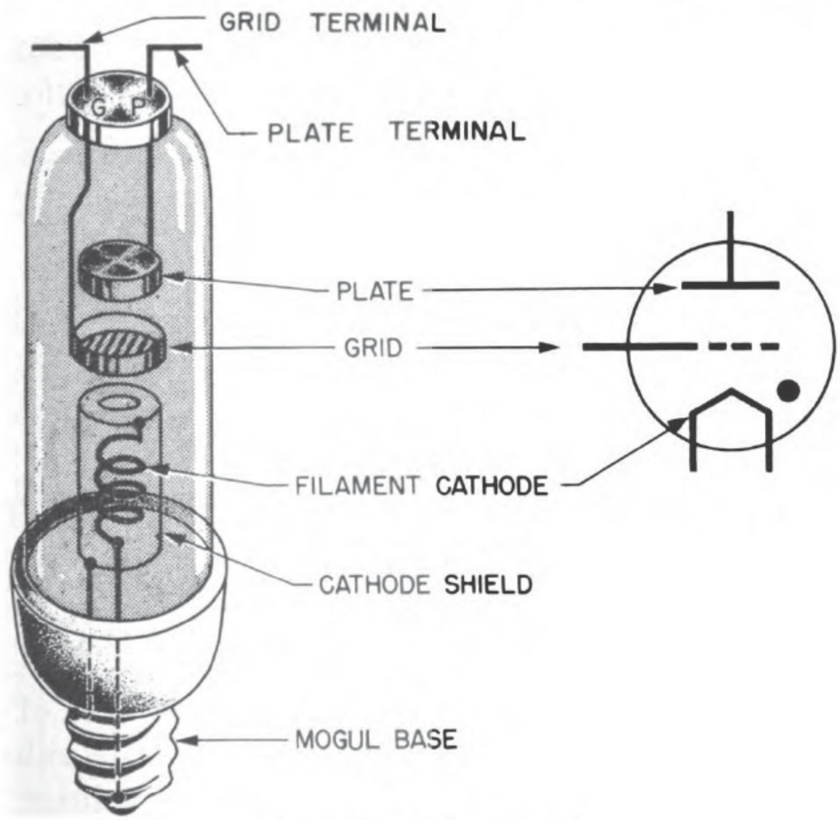


Figure 2—2.—Thyratron.

the filament from positive-ion bombardment. Filament current is supplied by a low-voltage transformer (about 5 volts). The grid is made of nickel or molybdenum and is of open construction to permit the free passage of electrons. The plate is composed of the same material as the grid but is of solid construction. The envelope is usually

made of glass and contains an inert gas, such as mercury vapor.

Principle of Operation

The grid of a gas triode functions somewhat the same as that of an ordinary vacuum tube but the resultant control action is entirely different. The output waveform of a gas triode (fig. 2–3) does not have the same shape as the input waveform. Also current flow may be initiated at any time during the positive half cycle, depending on the grid bias in relation to the plate voltage. Once the current flow is started, the grid loses control over the flow

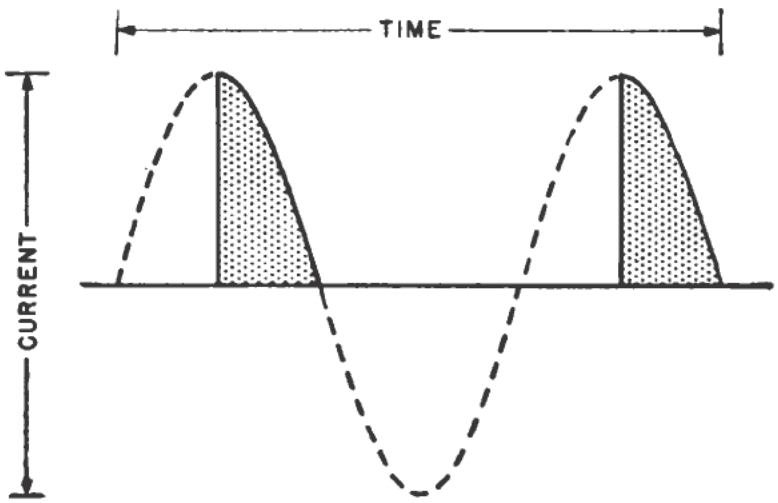


Figure 2—3.—Output waveform of a gas triode.

of electrons in the tube. The grid loses its sheath of positive ions when the plate voltage falls below the value required to maintain ionization. As the plate voltage rises in a positive direction during the next positive half cycle, the grid is in a condition to again assume control of the start of plate current flow. As in the diode, there is no current flow during the negative half cycle. Because the output waveform does not have the same shape as the input waveform, the gas tube cannot be used as an amplifier or signal detector. Although a vacuum diode rectifier and a gas triode rectifier accomplish rectification, the vac-

uum tube acts like a one-way valve; whereas, the gas tube provides a method of controlling the amount of current.

The purpose of the grid in the gas tube is to control the time in each cycle of applied voltage at which the tube begins to conduct. When ionization occurs, the internal resistance of the tube drops to a small value and a large current flows immediately.

The ionization potential depends upon both the plate potential and the grid potential. The grid-control characteristics of a typical thyratron are shown by the curve in figure 2–4. The curve indicates the relation between grid voltage and positive plate voltage required to ionize the gas in the tube. For example, if the grid voltage is —8 volts the tube fires when the plate voltage exceeds 800

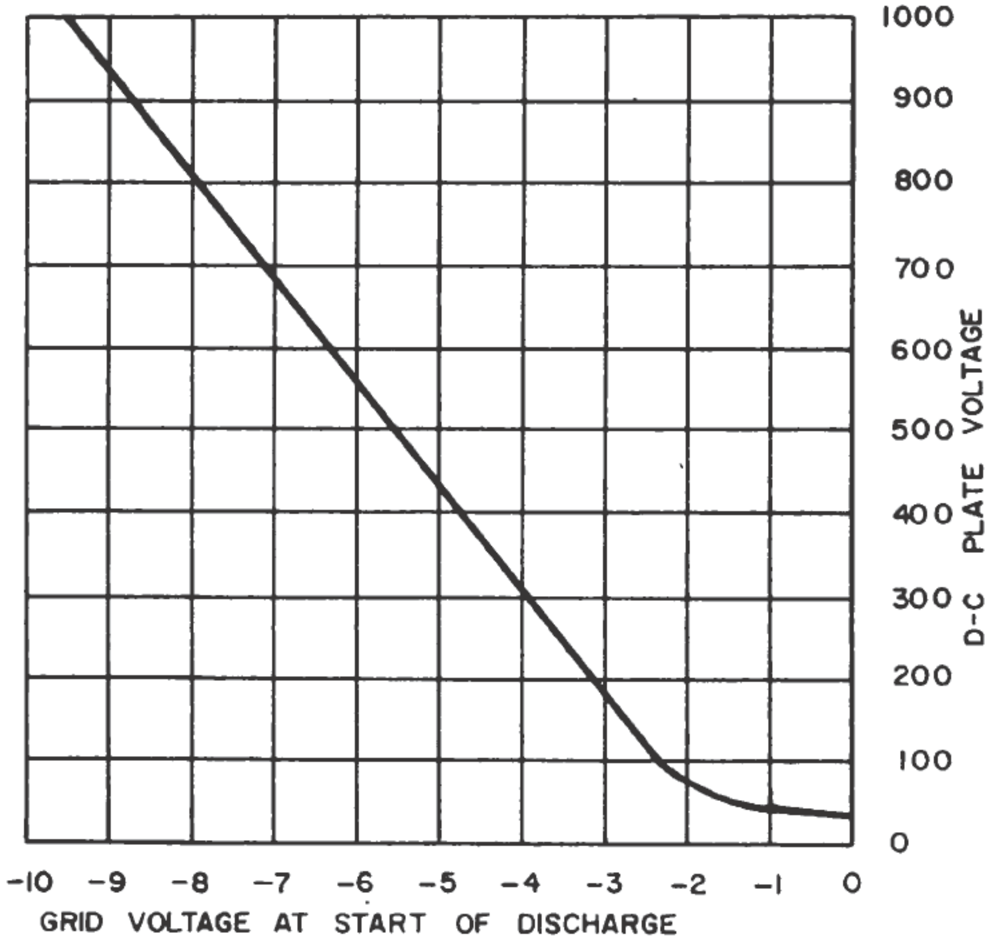


Figure 2—4.—Grid-control characteristics of a typical thyratron.

volts, and when the grid bias is —4 volts the tube fires when the positive plate voltage exceeds 300 volts. Thus the lower the bias voltage the lower is the positive plate voltage at which the tube fires. The grid-plate voltage curve thus separates the graph into two areas. The one at the upper right represents grid-plate voltage relations in which the tube is conducting, and the area at the lower left represents conditions in which the tube is non-conducting. For example, if the grid voltage is —5 volts, the tube will conduct if the positive-plate voltage is 800 volts, but will not conduct if the positive-plate voltage is increased from zero to only 300 volts.

In a high-vacuum triode the grid retains complete control of the current flowing in the tube because it retains its negative charge throughout the entire cycle. However, in a gas-filled tube, when conduction starts the grid loses control of the current flow because a sheath of positive ions is formed around the grid, which neutralizes the negative charge on the grid. Plate current continues to flow only as long as the plate voltage remains positive and exceeds the deionization voltage. When the plate voltage falls below this value, the tube deionizes and becomes non-conducting. The grid then loses its sheath of ions and regains its bias control. Hence, the grid of a gas tube can be made to repeatedly start or delay the flow of current only if the voltage applied to the plate periodically drops below the deionization potential so that the grid regains control after losing it.

The thyratrons used in I. C. and F. C. equipment require large amounts of power and invariably use a-c plate voltages. The current in the plate circuits of these tubes is controlled by one of three methods of grid-voltage control that are known as (1) amplitude, (2) phase-shift, and (3) saw-tooth methods of grid control.

Amplitude Control

D-C GRID VOLTAGE.—Amplitude control using a d-c grid voltage is shown by the E_p-E_g curves in figure 2–5. With

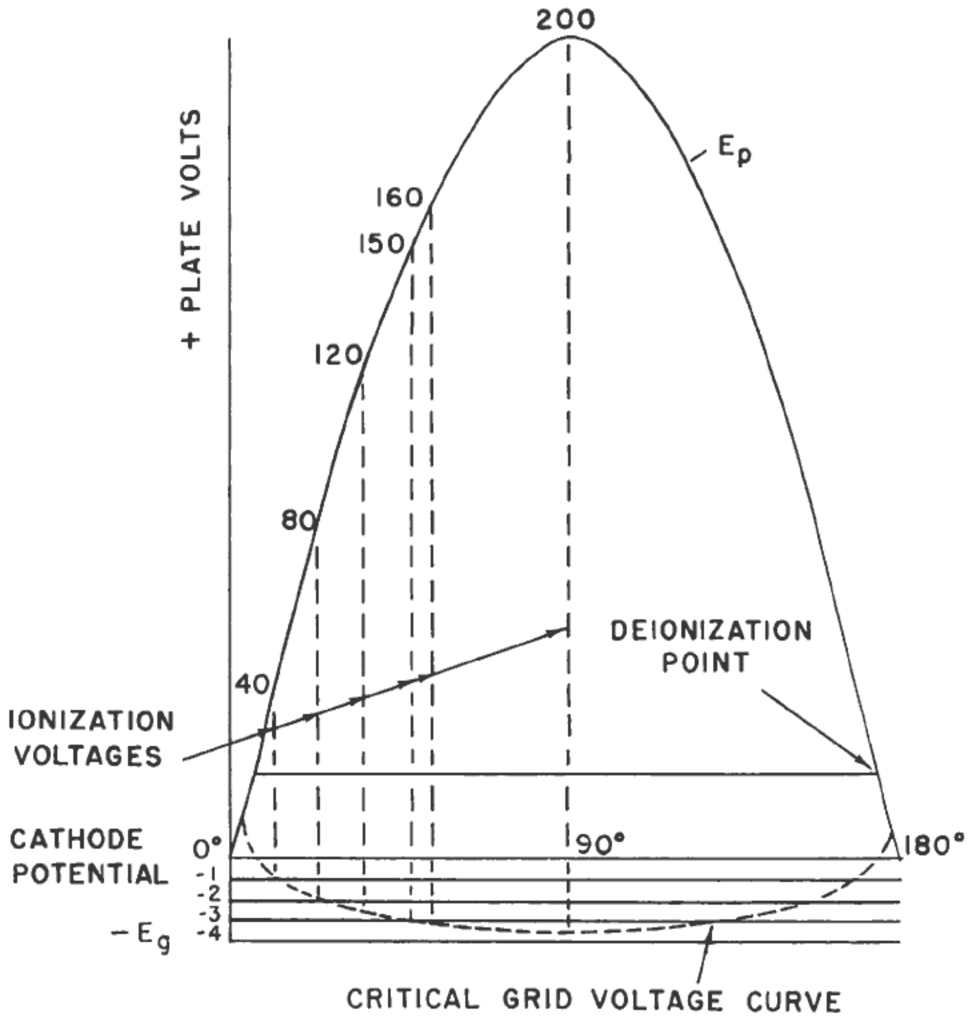


Figure 2—5.—Amplitude control using a d-c grid voltage.

—2 volts on the grid, the tube fires from 80 volts of plate voltage to the deionization potential. With —3 volts on the grid, the tube fires from 150 volts to the deionization potential. Thus, the more negative the grid voltage, the shorter will be the period of conduction. With —4 volts on the grid, the tube is completely cut off and will not fire at all during any portion of the cycle. But with —1 volt on the grid the tube fires at 40 volts and conducts through the greater portion of the positive half cycle. In other words, the amplitude of the d-c grid voltage in relation to the amplitude of the positive plate voltage determines when the tube will fire.

is applied, and E_s is in phase with E_p (fig. 2-8,B), then E_s and E_c are 120° out of phase and add vectorially to produce the resultant, E_g. Therefore, E_s makes E_g lag E_p by only 105°, as shown in the vector diagram. Hence, E_g intersects the critical grid voltage curve earlier in the positive half-cycle of plate voltage and the tube fires at about 90°. The shaded area shows that phase shift has advanced the firing point and that the tube passes more I_p.

If E_s is increased in magnitude, E_g will lag E_p by a smaller angle, for example, only 60°, as shown in the vector diagram (fig. 2–8, C). Hence E_g intersects the critical grid voltage curve earlier in the positive half cycle of E_p and the tube fires at about 40°. The shaded area shows that the phase-shift has advanced the firing point and that the tube passes nearly maximum I_p.

Summarizing this action, it is apparent that the addition of E_c and E_s in the grid circuit produces the resultant E_g, which determines the firing point of the tube. The magnitude of E_s determines the phase shift of E_g and the phase shift controls the firing point. Hence, the magnitude of E_s determines the magnitude of I_p. The magnitude of E_s can be changed by different methods, such as a synchro network, a variac, or a rheostat.

Phase-shift control for a full-wave rectifier circuit is shown by the E_p-E_g curves in figure 2–9. E_c is 120° out of phase with E_p. As in the half-wave systems, E_s and E_c add to produce the total E_g. E_g is fed to a transformer the secondary of which has a center tap. This center tap splits E_g into E_{g1} (composed of $E_{c1} + E_{s1}$) and E_{g2} (composed of $E_{c2} + E_{s2}$), and makes E_{g1} and E_{g2} 180° out of phase. Hence the components E_{s1} and E_{s2} are also 180° out of phase. Therefore, when E_{p1} is positive, E_{s1} is positive (fig. 2-9,A) and when E_{p2} is positive E_{s2} is positive (fig. 2–9,B). The vectors show that the magnitude of E_s determines the phase of E_g. As the phase of E_g controls the firing point, the magnitude of E_s controls the amount of I_p.

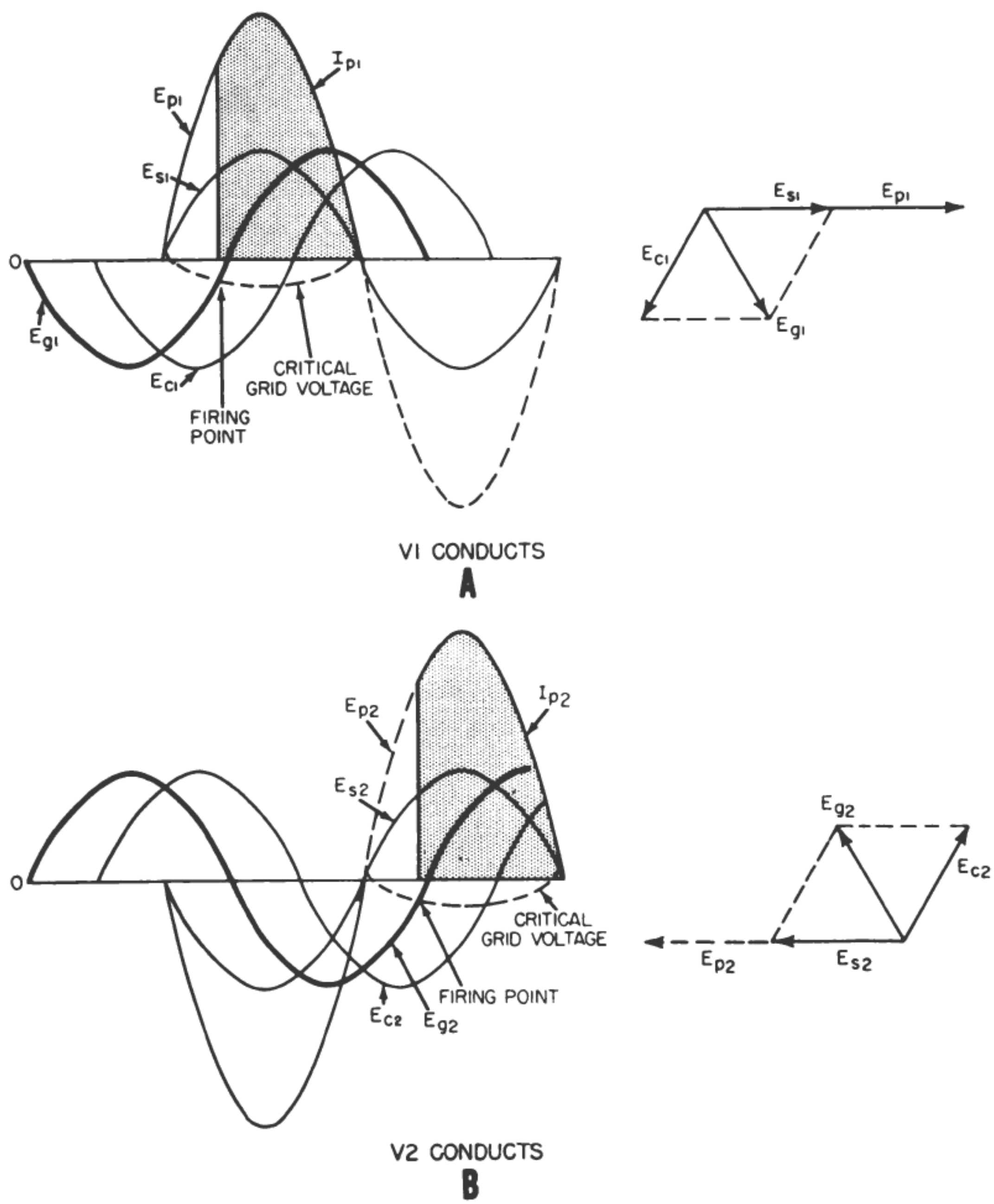


Figure 2—9.—Full-wave phase-shift control using two a-c grid voltages.

Saw-Tooth Control

Saw-tooth control is accomplished by means of two grid voltages, as shown by the E_p-E_g and the E_c curves in figure 2–10. The first grid-voltage, E_c, is a steady positive d-c voltage, which acts in series with a second grid-voltage of special waveform. The second grid-voltage,

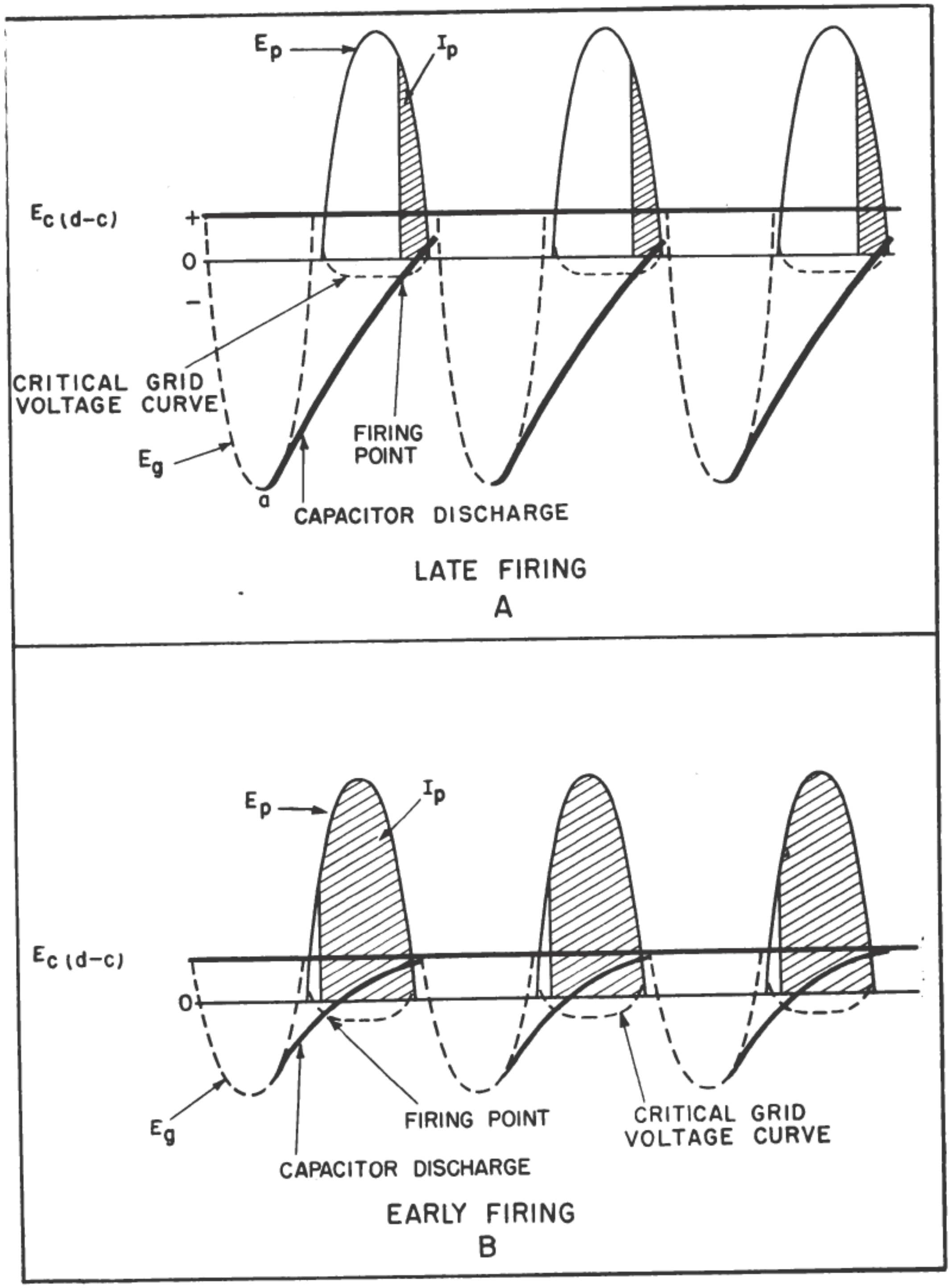


Figure 2—10.—Saw-tooth control.

E_g, is a saw-tooth voltage that is negative over nearly all of the input cycle of applied voltage. Thus the two voltages are in series opposition over nearly all of the input cycle.

The tube fires when the saw-tooth voltage curve intersects the critical grid-voltage curve. To make the thyratron fire late (fig. 2–10,A), the amplitude, which controls the slope of the saw-tooth voltage curve, is increased so that it intersects the critical grid voltage curve LATER. Conversely, to make the thyratron fire early (fig. 2–10,B), the amplitude of the saw-tooth voltage curve is decreased so that it intersects the critical grid voltage curve EARLIER. Thus large E_g saw-tooth pulses produce LATE firing, and small E_g saw-tooth pulses produce EARLY firing. Therefore the firing point can be made early or late by regulating the magnitude of the E_g pulses. It is apparent with saw-tooth control that the conduction cycle may be initiated anywhere between 0° and 180°. In this respect saw-tooth control is similar to phase-shift control.

THYRATRON RECTIFIER CIRCUITS

Thyratron control for servomechanisms, or followup systems, is being replaced by the amplidyne and electrohydraulic types because thyratrons are expensive to build, require a large space, and are sensitive to shock. However, a knowledge of thyratron control is essential because thyratrons are still used in the older sperry searchlights and in some gyrocompass followup systems.

Half-Wave Circuits

AMPLITUDE CONTROL.—The circuit of a half-wave rectifier with amplitude control using a d-c grid voltage is shown in figure 2–11. When the variable-resistance arm of the potentiometer is in position 1, E_g has a small value which advances the firing time so that the tube passes current for most of the conducting half-cycle of the applied voltage. The shaded areas ① of the E_p-E_g and the I_p curves show that the tube fires early and that the aver-

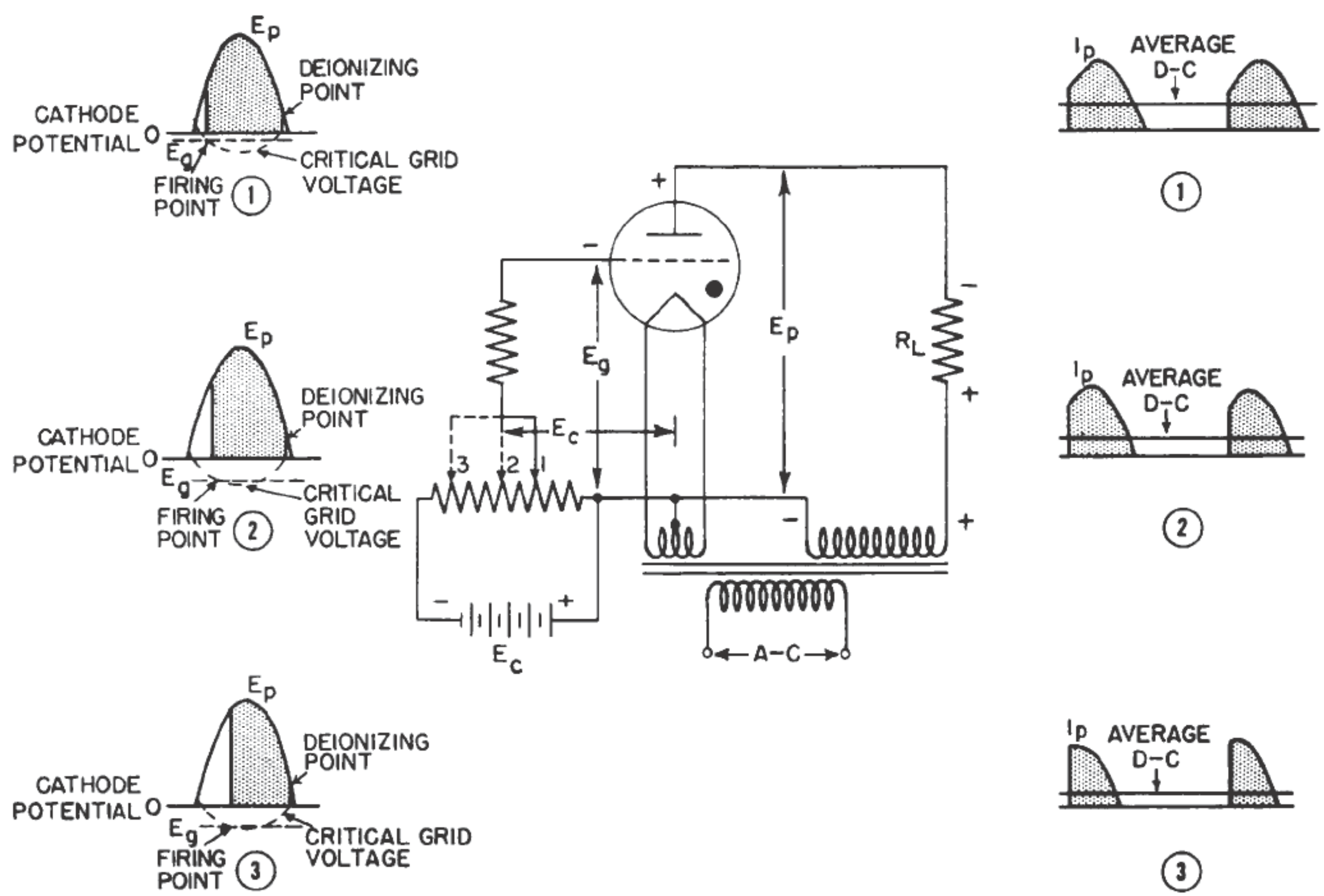


Figure 2—11.—Half-wave rectifier with amplitude control.

age value of the direct current through the load is relatively large. The first part of each conducting half cycle is cut off because E_g exceeds the critical grid voltage, and the last part is cut off because E_p falls below the deionizing potential.

When the variable-resistance arm of the potentiometer is in position 2, E_g is increased and the tube passes current for a shorter time. The shaded areas ② of the E_p-E_g and the I_p curves show that the tube fires later and that a smaller average direct current flows through the load.

When the variable-resistance arm of the potentiometer is moved to position 3, E_g is further increased and the firing time is further delayed so that the tube passes current for only about half the alternation. The shaded areas ③ of the E_p-E_g and the I_p curves show that the tube fires later and that a smaller average direct current flows through the load.

PHASE-SHIFT CONTROL.—The circuit of a half-wave rectifier with phase-shift control using two a-c grid voltages in series is shown in figure 2–12. This circuit produces the voltage waveforms shown in figure 2–8. The grid voltage, E_s, comes from synchro control transformer CT, which is supplied in turn by synchro transmitter T from one phase of a 3-phase power source. E_p of the thyratron is also supplied from the same phase that

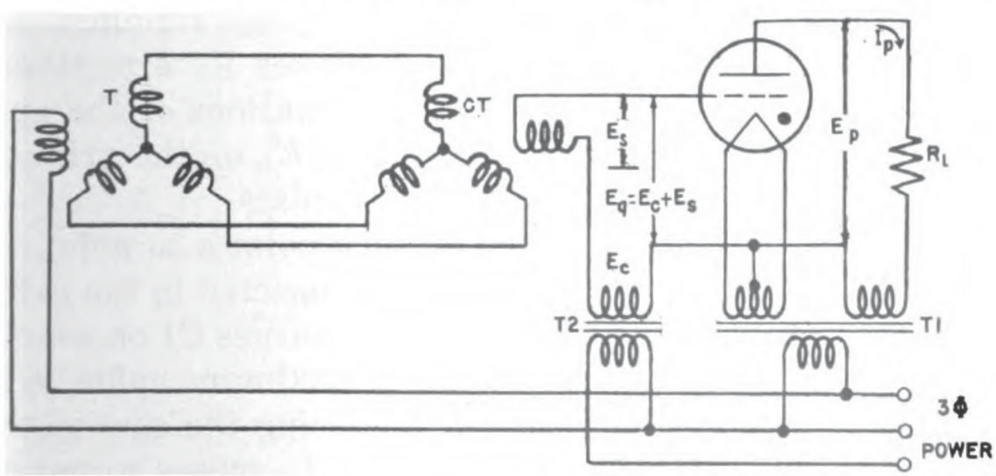


Figure 2—12.—Half-wave rectifier with phase-shift control.

supplies E_s. Because E_s and E_p come from the same phase of the 3-phase source, they are either in phase or 180° out of phase, depending upon the direction in which the synchro transmitter rotor is turned. E_c can control the thyratron only when E_s and E_p are in phase, as shown in figure 2–8. Thus, E_s will control the thyratron only when the transmitter rotor is turned in the proper direction.

The second grid voltage, E_c, comes from transformer $T2$ which is supplied from another phase of the same 3-phase power source. Thus, E_c is 120° out of phase with E_s and E_p. E_s and E_c add vectorially to produce the resultant grid voltage E_g, as shown by the vectors of figure 2–8. The phase displacement of E_g is determined by the relative magnitude of E_s with respect to E_c.

If E_s is a small value, the resultant E_g will be nearly in phase with E_c and the tube will fire at approximately 90°, as shown in figure 2-8,B. Conversely if E_s is approximately equal to E_c, the resultant E_g will be approximately 60° out of phase with E_s and the tube will fire earlier, as shown in figure 2–8,C.

SAW-TOOTH CONTROL.—The circuit of a half-wave rectifier with saw-tooth control is shown in figure 2–13. $V1$ with networks $R1$-$C1$ comprise the saw-tooth generator and thyratron $V2$ is the half-wave rectifier.

The plate supply of $V1$ is an a-c voltage supplied by transformer $T1$. This plate supply makes $V1$ a rectifier that passes current only on the B alternations of the applied voltage. Also, the signal voltage, E_s, on the grid of $V1$ controls the magnitude of the I_{p1} pulses.

The I_{p1} pulses flow through R1 from point a to point b, making point a negative. Point a is connected to the grid of thyratron $V2$. The $R1$ voltage also charges $C1$ on every pulse of I_{p1}. When I_{p1} reaches its maximum value, $C1$ begins to discharge through R1, producing the saw-tooth voltage, E_g. Thus, $R1$ and $C1$ use the I_{p1} pulses to put a saw-tooth voltage on the grid of $V2$.

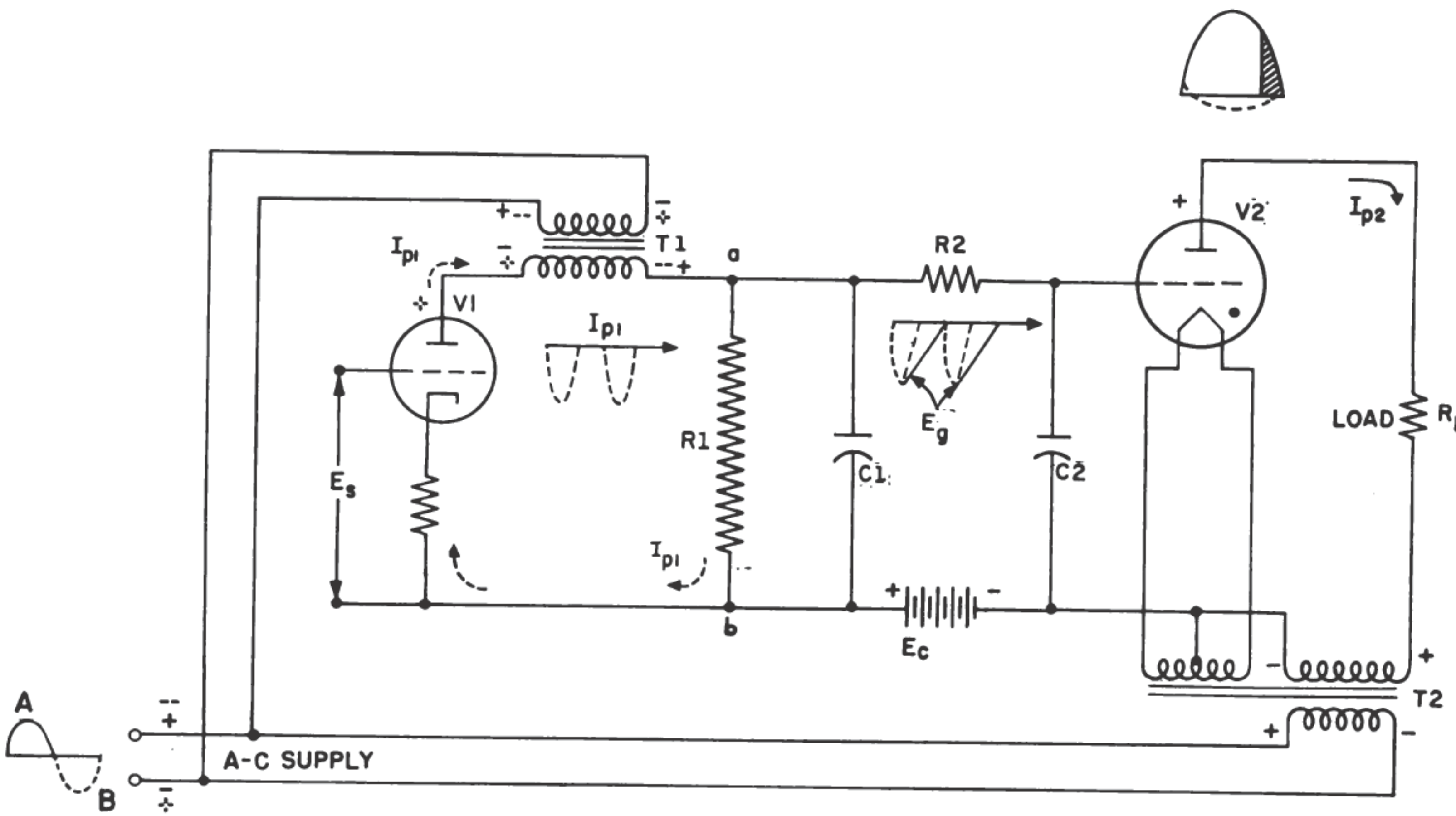


Figure 2—13.—Half-wave rectifier with saw-tooth control.

With no signal on the grid of $V1$, the I_{p1} pulses are large, producing a large saw-tooth voltage, and the thyratron fires LATE. With a negative signal, E_s, on the grid of $V1$, the I_{p1} pulses are reduced, reducing the saw-tooth voltage and the thyratron fires EARLIER. Thus, E_s on the grid of $V1$ controls the firing point of $V2$.

The C-supply, E_c, on the grid of $V2$ is positive because it comes from the positive terminal of the battery. This positive E_c is the reference voltage for the saw-tooth voltage, E_g. These voltages are opposed to each other. Transformer $T1$ makes the plate of $V1$ positive during the B alternation and transformer $T2$ makes the plate of $V2$ positive during the A alternation. Hence, I_{p1} drives the grid of $V2$ to cut-off during each B alternation. During each A alternation, when the plate of $V2$ is positive, the grid of $V2$ is controlled by the discharge of $C1$.

The $R2$–$C2$ network acts as a filter to keep the $V2$ grid surges out of the saw-tooth circuit. $C2$ also keeps E_c constant because $C2$ is charged by the E_c battery.

Full-Wave Circuits

UNIDIRECTIONAL PHASE-SHIFT CONTROL.—The circuit of a unidirectional full-wave rectifier with phase-shift control is shown in figure 2–14. This circuit consists of two thyratrons, $V1$ and $V2$, connected so that the voltages on the plates are 180° out of phase. Likewise, the voltages on the corresponding grids are 180°out of phase so that one tube or the other is always ready to fire.

The plate supply for the full-wave rectifier comes from transformer $T1$. This transformer and the synchro supply are energized by the same phase of the 3-phase power source. The plates of $V1$ and $V2$ are 180° out of phase because they are connected to opposite ends of $T1$.

E_c comes from $T3$ which is energized by another phase of the 3-phase power source. Thus, E_c is 120° out of phase with E_p. E_s comes from $T4$ which is energized from the same phase of the 3-phase power source as the plate supply. E_c and E_s are in series with $T2$ and combine to de-

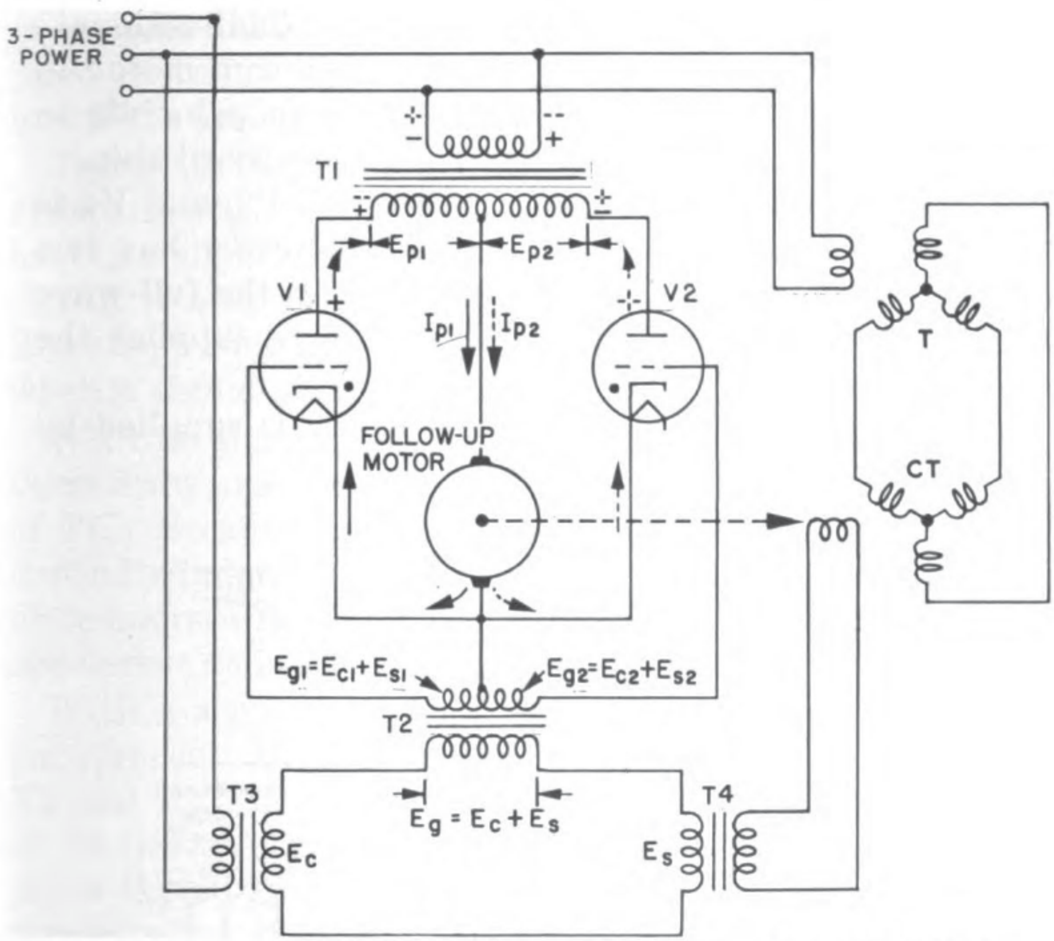


Figure 2—14.—Unidirectional full-wave rectifier with phase-shift control.

velop the grid bias, E_g. The center tap at $T2$ splits E_g into E_{g1} and E_{g2}, and these two biases are 180° out of phase. Hence, the components E_{s1} and E_{s2} also are 180° out of phase. Therefore, when the plate of $V1$ is positive, E_{s1} is positive and when the plate of $V2$ is positive, E_{s2} is positive (fig. 2–9).

E_s and E_c add vectorially to produce the resultant, E_g. Also the phase of E_g with respect to E_p depends on the magnitude of E_s as compared with that of E_c. Thus, the magnitude of E_s determines the firing time of the tube and the amount of I_p. I_{p1} and I_{p2} both flow through the armature of the d-c followup motor. Therefore, E_s controls the speed of the followup motor.

BIDIRECTIONAL PHASE-SHIFT CONTROL.—A simplified circuit of a bidirectional full-wave rectifier with phase-shift

control is shown in figure 2–15. The term "bidirectional" means that the system will drive the followup motor in either direction. This system is similar in principle to many gun and searchlight drives installed aboard ship.

The a-c voltage for the plates of *V*1, *V*2, *V*3, and *V*4 is supplied by transformer *T*1. This transformer has two secondary windings. One winding supplies the full-wave rectifier, *V*1 and *V*2, and the other winding supplies the full-wave rectifier, *V*3 and *V*4.

E_c, which is 120° out of phase with E_p, is supplied by

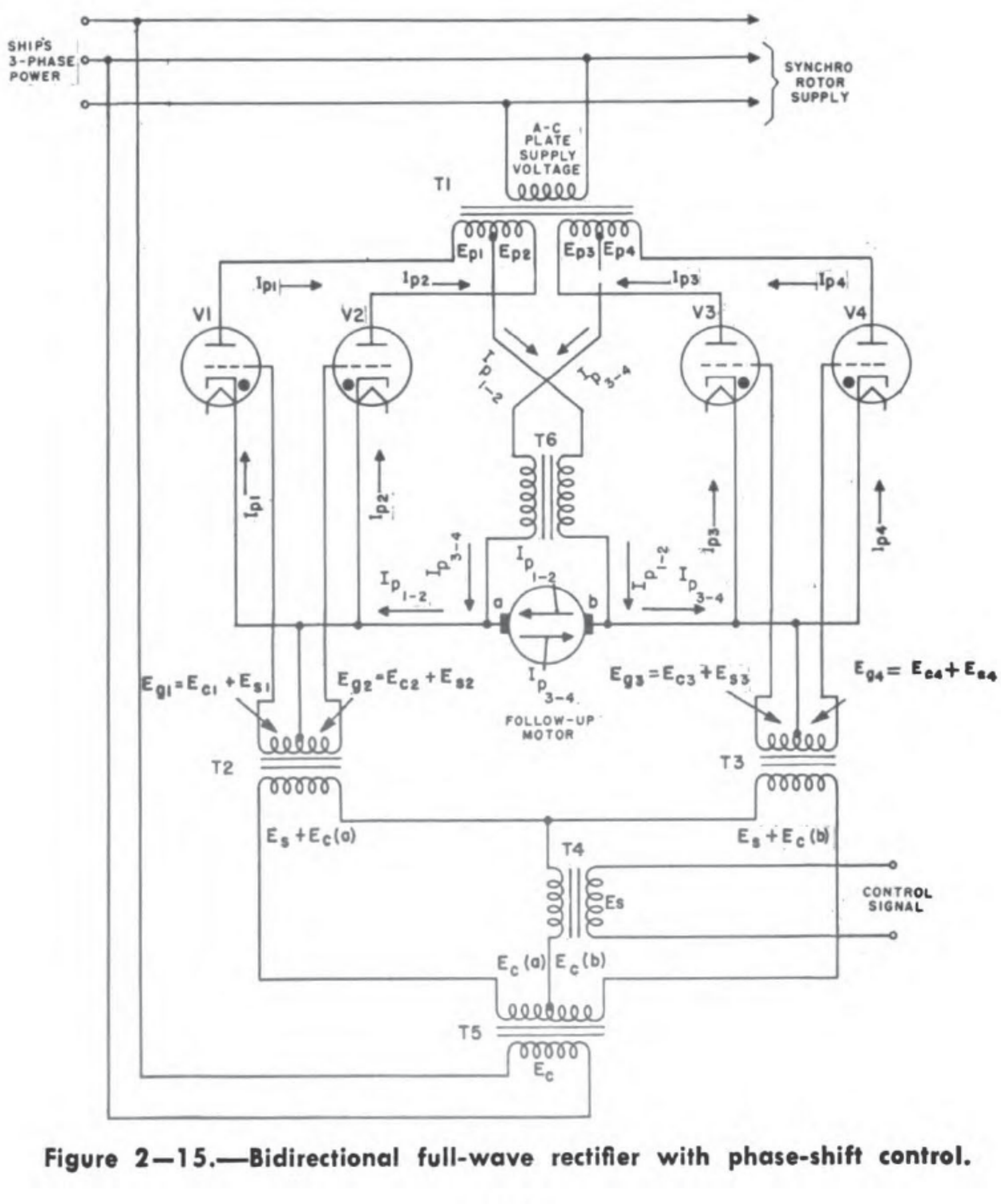


Figure 2—15.—Bidirectional full-wave rectifier with phase-shift control.

transformer $T5$. E_s, which is in phase with E_p, is supplied by transformer $T4$. E_s is combined with E_c at $T2$ and $T3$ to produce the total E_g for each pair of thyratrons.

The plate currents of all four tubes flow through the armature of the d-c followup motor. $T6$ is a transformer having a slightly different application than usual. In this circuit it acts as a double-reactor choke that limits the thyratron currents on no signal, and unbalances them when a signal is introduced.

With no signal present, the plate currents of the four thyratrons are divided equally between the two windings of $T6$. Because they are pulsating, the self-induced and mutually induced voltages in the two windings oppose the plate-current flow and limit it. With no signal, the voltage across *ab* is zero and there is no armature current.

With a signal present, the thyratron currents become unbalanced. If the signal increases the plate currents of $V1$ and $V2$, the I_{p1}-I_{p2} currents in the right-hand winding of $T6$ induce a voltage in the left-hand winding that opposes the I_{p3}-I_{p4} currents and reduces them. The I_{p1}-I_{p2} currents flow through the armature from *b* to *a* and cause clockwise rotation. If the applied signal increases the plate currents in $V3$ and $V4$, the left-hand winding of $T6$ carries most of the current, and the flow through the armature is from *a* to *b*, thus reversing the direction of rotation of the armature.

TWO-SPEED BIDIRECTIONAL PHASE-SHIFT CONTROL.—Two-speed self-synchronous systems are used in gyrocompass repeaters, gun directors, and other equipment requiring a high degree of followup accuracy. In such a system coarse control is furnished by one synchro unit and fine control by another. The coarse-control, or low-speed, synchro usually makes only 1 revolution during the full travel of the load; whereas, the fine-control, or high-speed, synchro usually is geared to make 18 or 36 revolutions. The speed of the synchros (1-speed, 18-speed, 36-speed) is merely the gear ratio with reference to the load.

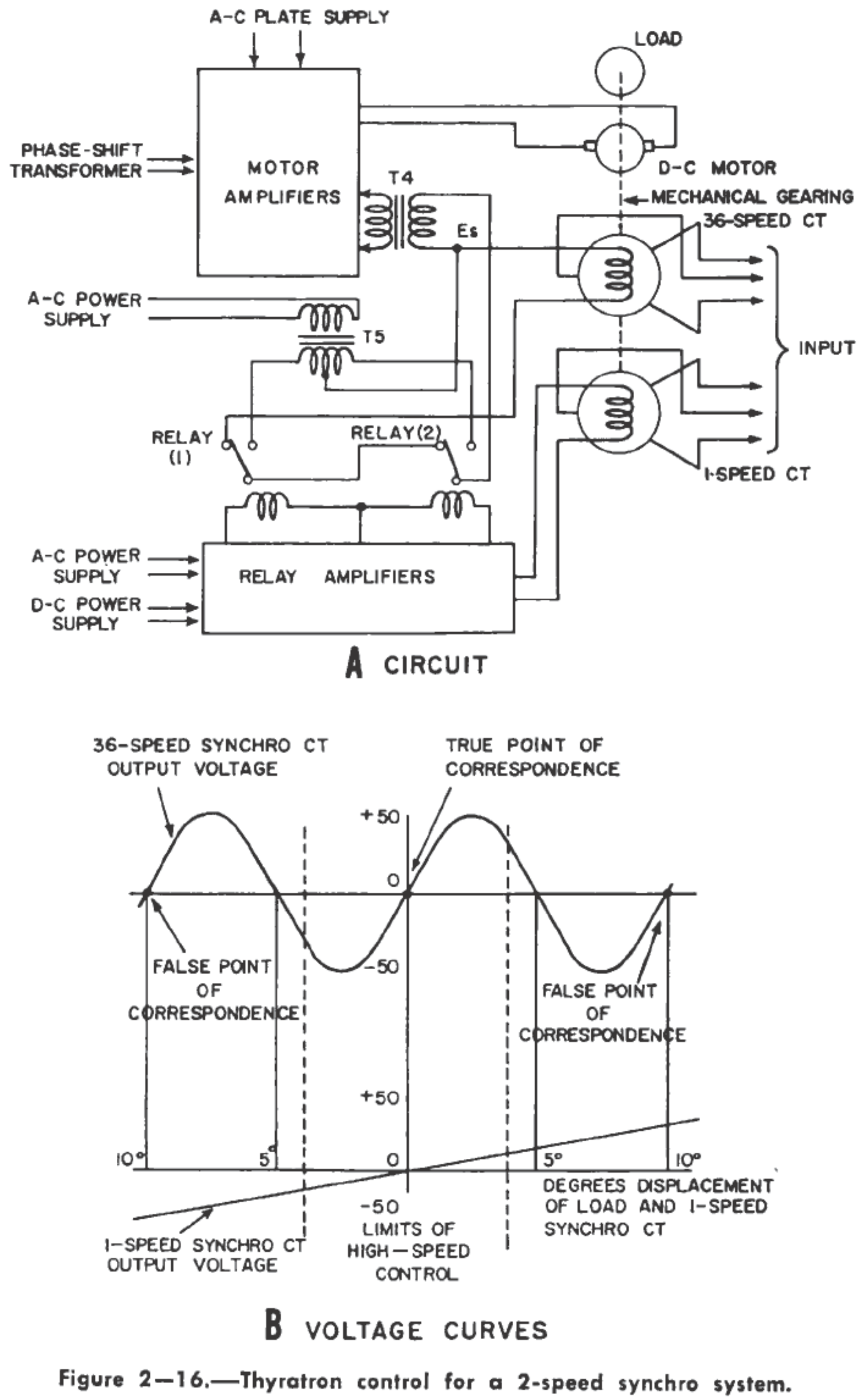


Figure 2—16.—Thyratron control for a 2-speed synchro system.

A 1-speed and a 36-speed synchro control transformer (*CT*) are shown connected to a load in figure 2–16,A. The 1-speed *CT* is used to connect the 36-speed *CT* to its output circuit. The 1-speed *CT* performs this action by energizing relays 1 or 2 when the 36-speed *CT* is within 5° of correspondence of the 1-speed *CT*, as indicated in the voltage curves of figures 2–16,B. Two false points of correspondence at which the 36-speed receiver alone might synchronize are shown on either side of the true point of correspondence.

The true point of correspondence is the point at which the rotor voltages of both the 1-speed and the 36-speed *CT's* are zero. During normal operation the system is always very close to this point and operates entirely from the 36-speed unit. When the system is out of step because of switching on and off, or when initially starting up, it is necessary to rely on the 1-speed unit to select the true point of correspondence. This selection is accomplished by a relay system. When the displacement exceeds 40 percent of 1 revolution of the 36-speed unit, indicated by the broken lines, the 36-speed synchro unit is disconnected from transformer *T*4 that supplies the control voltage, E_s, and a synchronizing voltage is applied to *T*4 instead. Conversely, when the displacement comes within this limit, the relay system restores control to the 36-speed synchro.

The circuit of a bidirectional full-wave rectifier with phase-shift control for a 2-speed synchro system is shown in figure 2–17. This circuit is the same as that shown in figure 2–15, except for the addition of the relay system. This relay system consists of high-vacuum triodes *V*5 and *V*6, plate transformer *T*8, grid transformer *T*7, and d-c bias potentiometer *P*. Triodes *V*5 and *V*6 operate as small half-wave rectifiers having a common a-c plate-voltage supply. The plates of *V*5 and *V*6 are connected in parallel. Relay 1 has its pickup coil connected in series with the plate of *V*5 and operates when this tube passes current.

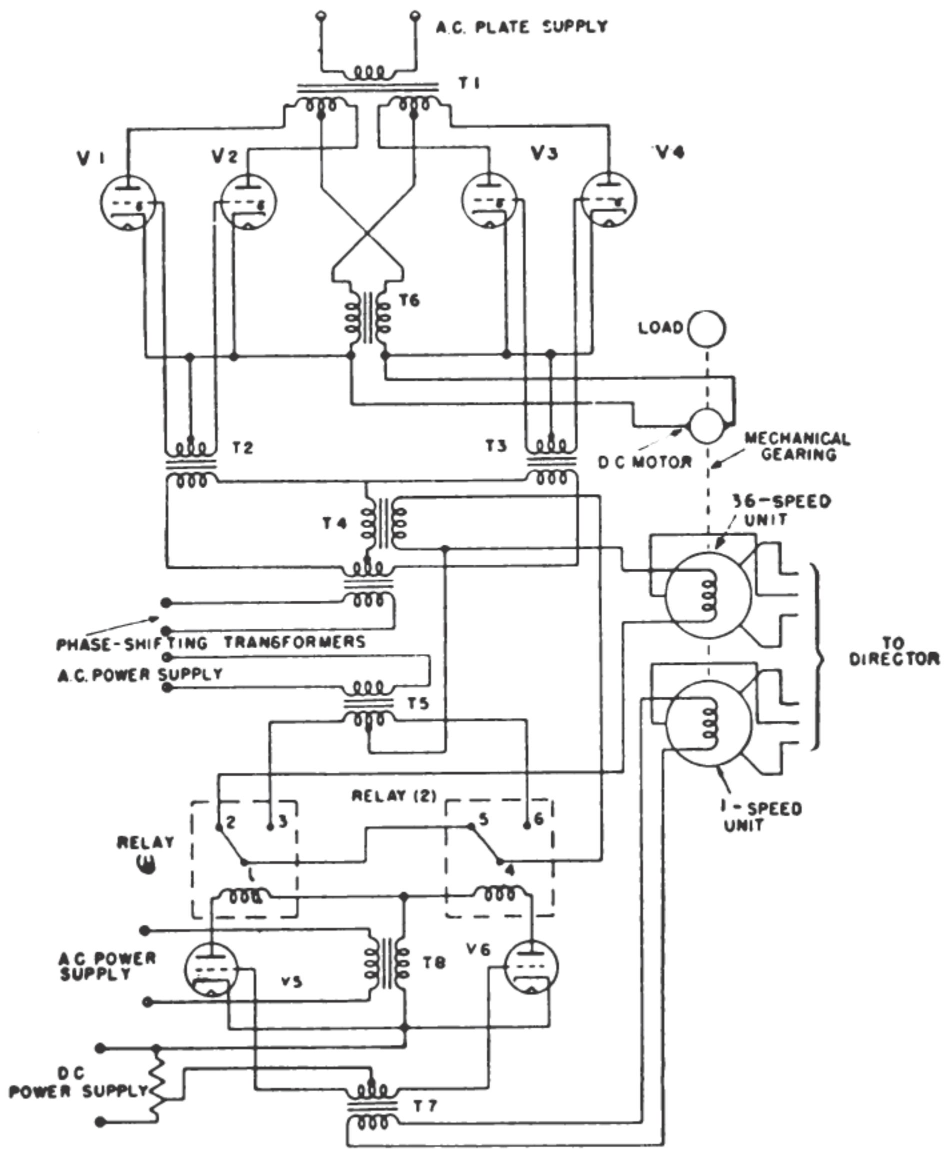


Figure 2—17.—Bidirectional full-wave rectifier with phase-shift control for a 2-speed synchro system.

Relay 2 has its pickup coil connected in series with the plate of *V*6 and operates when this tube passes current. The grids of *V*5 and *V*6 are connected in push-pull.

A constant negative d-c bias is applied to the grids of *V*5 and *V*6 by means of the potentiometer. The error signal from the 1-speed *CT* is applied to the grids in series with the d-c bias through *T*7. The magnitude of the error signal necessary to operate the relays can be varied by adjusting the potentiometer. When both plates are negative, neither tube can conduct. When the plates are posi-

tive, either tube may conduct. The tube that conducts will have the same polarity on its grid and plate and thus will operate its relay, provided the error signal is of sufficient magnitude. When the polarity of the error signal is reversed by displacement of the 1-speed *CT* in the opposite direction, the grid of the other tube is positive when both plates are positive and this tube now operates its relay.

The 36-speed *CT* is connected to *T*4 with one lead connected through the normally closed contacts 1–2 and 4–5 of relays 1 and 2 respectively. If the load is sufficiently displaced in one direction (error signal has sufficient amplitude), relay 1 will operate and cause its contact 1–2 to open and contact 1–3 to close. When contact 1–2 opens, it disconnects the 36-speed *CT* from *T*4, thus removing control from this unit. When contact 1–3 closes, a synchronizing voltage is impressed from one-half the *T*5 secondary to *T*4. This synchronizing voltage is of such a direction that the grids of the thyratron cause the d-c servomotor to position the load toward the point of correspondence. When the displacement becomes sufficiently small, the rotor voltage (error signal) of the 1-speed *CT* has no further effect on the grids of the high-vacuum triodes and relay 1 drops back to its normal position, thus removing the synchronizing voltage and restoring control to the 36-speed *CT*. Similarly, if the load is sufficiently displaced in the other direction, the polarity of the error signal is reversed, and relay 2 operates to apply a voltage of opposite polarity from the other half of *T*5 to *T*4. This action causes the load to come into its true point of correspondence from the other direction.

BIDIRECTIONAL SAW-TOOTH CONTROL.—The circuit of a bidirectional full-wave rectifier with saw-tooth control is shown in figure 2–18. This system is essentially two half-wave rectifiers, *V*3 and *V*4, the grids of which are supplied a d-c voltage, E_c, from the positive side of the same *C*-supply. The plate voltages for *V*1 and *V*2 are supplied by transformer *T*1, which has two secondaries that isolate

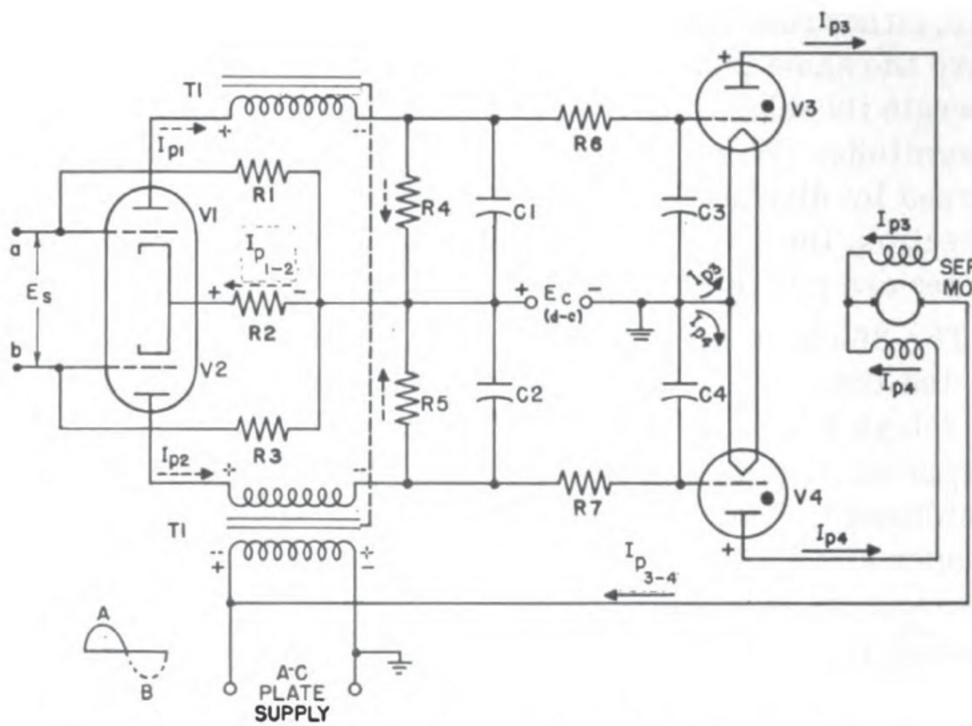


Figure 2—18.—Bidirectional full-wave rectifier with saw-tooth control.

the two plate circuits from each other. These secondaries are phased so that the $V1$ and $V2$ plates go positive together on the negative half cycles of the primary a-c plate supply voltage. The plates of $V3$ and $V4$ are in phase with each other and 180° out of phase with the plates of $V1$ and $V2$.

The saw-tooth generator for thyratron $V3$ consists of $V1$, $R4$, and $C1$. Thus, the firing point of $V3$ is controlled by the signal on the grid of $V1$. Likewise, the saw-tooth generator for thyratron $V4$ consists of $V2$, $R5$, and $C2$. Thus, the firing point of $V4$ is controlled by the signal on the grid of $V2$.

The load is a series followup motor having two field windings. These windings are energized by thyratrons $V3$ and $V4$. When $V3$ fires, the top field is energized and the motor drives in one direction. Conversely, when $V4$ fires, the bottom field is energized, and the motor drives in the opposite direction.

When there is no signal between points a and b, I_{p1} and

I_{p2} are equal; I_{p3} and I_{p4} are small and equal; and thyratrons $V3$ and $V4$ fire at the same time—late. The motor fields are of equal strength and the motor does not drive.

An a-c signal voltage, E_s, applied to the grids of $V1$ and $V2$ may make point *a* more positive and point *b* more negative each time the $V1$ and $V2$ plates go positive, so that I_{p1} increases and I_{p2} decreases. In this case the amplitude of the saw-tooth voltage on the grid of $V3$ increases and that on the grid of $V4$ decreases. This action causes $V3$ to fire late and $V4$ to fire earlier. (See fig. 2–10.) The smaller I_{p3} weakens the top field and the larger I_{p4} strengthens the bottom field. Thus, the followup motor is driven in one direction by the bottom field.

On the other hand, if the E_s on the grids of $V1$ and $V2$ is reversed making point *b* more positive and point *a* more negative, each time the $V1$ and $V2$ plates go positive I_{p2} increases and I_{p1} decreases. This action causes $V4$ to fire later and $V3$ to fire earlier. The smaller I_{p4} weakens the bottom field and the larger I_{p3} strengthens the top field. Thus the followup motor is driven in the opposite direction by the top field.

QUIZ

1. (a) What is the relative degree of vacuum (higher or lower) in a gas-filled electron tube compared to that in a high-vacuum electron tube? (b) Why?
2. What is the relative peak inverse voltage rating of a gas-filled diode compared with that of its high-vacuum diode counterpart?
3. What is the relative efficiency of a gas-filled diode compared to that of its high-vacuum diode counterpart?
4. What specific load current characteristic makes the gas-filled diode suitable for control of various servo mechanisms and gyrocompass followup systems?
5. Upon what two factors does the power required to force electrons through a tube depend?
6. (a) Name three factors that determine the internal effective resistance of a high-vacuum tube.
   (b) How is the internal resistance lowered in a gas diode?
7. Why is it desirable to keep the voltage drop across an electron tube at a minimum?
8. Name the five types of generally used inert gases.
9. (a) How are ions formed in a hot-cathode gas diode?
   (b) What is the polarity of the charge on an ion in a gas diode?
10. What is the (a) effect of the ions on the space charge in the vicinity of the cathode, and (b) the result of this action on the emission current and the opposition to current flow?
11. Name the two factors that result from the automatic reduction of the space charge in a gas tube with increased load.
12. Name the five generally used expressions for the voltage at which ionization commences in a tube.
13. After ionization has started, is the voltage drop across the tube lower or higher than that of the firing point?
14. What action occurs if the voltage across the tube falls below the minimum value required to maintain ionization?
15. Name the two general expressions for the minimum voltage required to maintain ionization in a tube.
16. What are the relative values of resistance of a gas-filled tube before and after ionization?

17. What disadvantage is inherent in a gas tube with regard to its rectifying property when the plate has a high negative (inverse) voltage with respect to the cathode?

18. How does the peak inverse voltage rating of a gas tube vary with respect to the temperature and pressure of the gas in the tube?

19. What limitation with regard to positive-ion bombardment of the cathode is inherent in a gas tube when the plate voltage is increased to a high value?

20. At high frequencies what limitation is inherent in a gas tube?

21. Why cannot a gas tube be connected directly across a low-resistance source without a series limiting resistance?

22. What symbol identifies a gas-filled tube?

23. If insufficient time is allowed to heat the cathode of a hot-cathode gas diode before applying the plate voltage, why is the cathode likely to be damaged by positive-ion bombardment?

24. Why is the firing potential for a neon-glow tube higher than that for a hot-cathode tube?

25. What is the polarity of the electrode that is surrounded with a glow in the neon-glow tube?

26. Name the five normal uses of the neon-glow tube.

27. What is the principal difference between a high-vacuum triode or tetrode and a thyratron?

28. Why is a thyratron unsuitable for use as an amplifier or signal detector?

29. (a) What happens to grid control of current flow when ionization occurs in a gas-triode rectifier? (b) Why?

30. What action enables the grid to periodically regain control over the flow in a thyratron?

31. If the grid of a thyratron is —4.6 volts with respect to the cathode (fig. 2–4), at what value of plate voltage will the tube fire?

32. If the plate voltage of a thyratron is +300 volts with respect to the cathode (fig. 2–4) and the tube is nonconducting, is the grid voltage greater or less than —4 volts with respect to the cathode?

33. Name three methods of grid-voltage control used to control the plate current of thyratrons in I.C. and F.C. equipment.

34. Why is the range of the amplitude method of grid-voltage control limited from 0° to 90°?

35. Does shifting the phase of the a-c grid signal voltage (fig. 2–7) from 155° to 30° increase or decrease the average value of the plate current?

36. How are the two a-c grid voltages, E_s and E_c, connected to produce phase-shift control of a thyratron (fig. 2–8)?

37. How is saw-tooth control of a thyratron accomplished?

38. How is late and early firing related to the amplitude of the saw-tooth voltage (fig. 2–10)?

39. How is amplitude control varied in the half-wave rectifier circuit shown in figure 2–11?

40. How is phase-shift control varied in the half-wave rectifier circuit in figure 2–12?

41. What components comprise the saw-tooth generator in the saw-tooth control circuit of the half-wave rectifier shown in figure 2–13?

42. Why are two-speed self-synchronous systems as opposed to single-speed systems used in gyrocompass repeaters and gun directors?

43. What is the magnitude of the rotor voltages of both the 1-speed and the 36-speed synchros at the true point of correspondence as shown in figure 2–16?

CHAPTER 3

BASIC MECHANISMS

Basic mechanisms comprise many mechanical components of various I. C. systems. These components include shafts, gears, cams, ratchets, bellows, springs and friction disk and roller assemblies.

SHAFTS

Shafts are usually solid or hollow cylindrical steel rods. They are used to support pulleys, gears, and other rotating parts and to transmit power or motion by rotation.

Shaft Values

The rotation of a shaft can represent a quantity, such as direction in degrees, distance in yards, or speed in knots. When a shaft is turned, the magnitude of the quantity represented is changed. Rotation in one direction increases the value of the quantity; whereas, rotation in the opposite direction decreases the value.

Almost every shaft has a zero position at which the values of the quantity represented by the shaft is zero. One revolution of a shaft can represent any convenient unit value of the particular quantity. For example, one revolution can represent a direction of 3°, a distance of 100 yards, or a speed of 5 knots. A shaft having any one of these values would have a shaft value of 3°, 100 yards, or 5 knots respectively. SHAFT VALUE, therefore, is the value that a shaft develops in one revolution—that is, the value per revolution.

A dial attached directly to a shaft with its zero position matched to the zero position of the shaft (fig. 3–1,A) will indicate only the fraction, or degree, of turn up to one complete revolution. For example, if the shaft has a shaft value of 10° and is turned ½ revolution away from the zero position, the value indicated by the dial will be 5°. If the shaft is then turned 1 complete revolution farther, and in the same direction, the dial will again indicate 5° although the shaft is 1½ revolutions away from its zero position and the total value of the shaft turn is now 15°.

A counter geared to a shaft adjusted to read zero at the shaft zero position (fig. 3–1,B) will indicate the number of turns and the fraction of a turn, in the same units as the shaft value, that the shaft is moved from its zero position. If the shaft has a shaft value of 10° and is turned ½ revolution from its zero position, the counter will read 5°. If the shaft is then turned 1 complete revolution farther, and in the same direction, the counter will

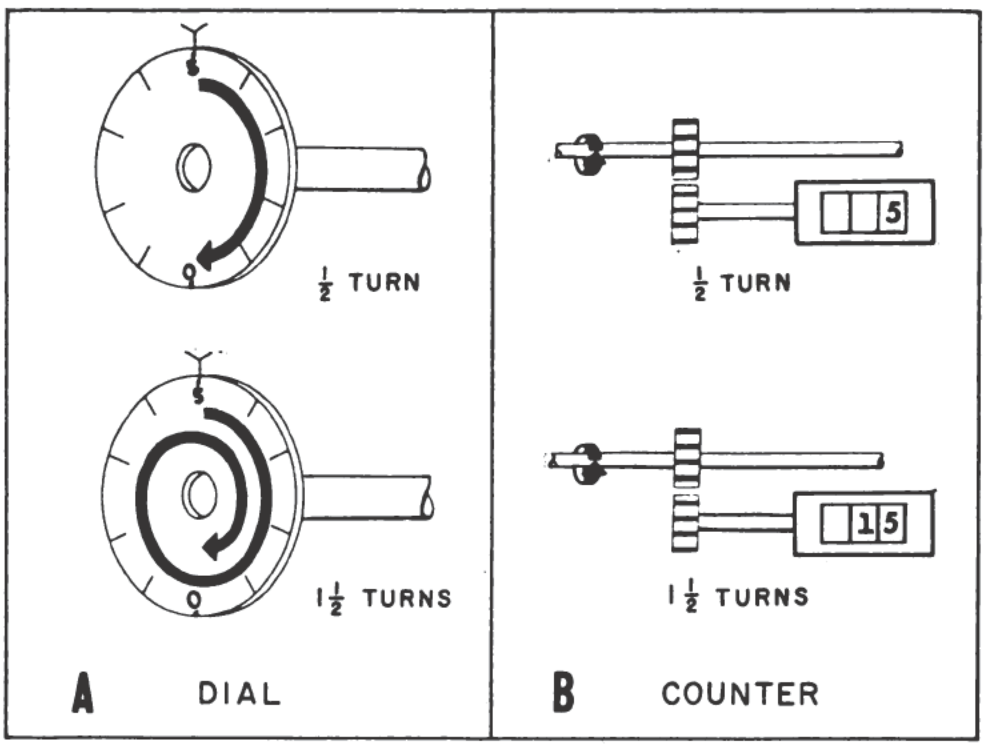


Figure 3—1.—Shaft values.

read 15°. If the shaft is now turned $1\frac{1}{2}$ revolutions in the opposite direction from the last resting position to decrease the total value, the counter will again read 0° because the shaft has been returned to its zero position.

The TOTAL VALUE always depends on the number of revolutions that the shaft is turned from its zero position. In other words, the total value is the product of the shaft value and the number of revolutions that the shaft is turned from its zero position.

GEARS

Gears are wheels with mating teeth cut into them so that one gear can turn another gear without slippage. When a gear positions another gear it transmits rotary motion.

If two mating gears are the same size, they will have the same number of teeth. One revolution of the driving gear will turn the driven gear one revolution because each tooth of the driving gear will push a corresponding tooth of the driven gear an equal distance across the center line of the two gears. If two gears are of different sizes, the smaller gear is usually called a PINION. When a gear and a pinion mesh together, their shafts turn at different speeds.

When a gear positions a rack, it converts rotary motion into motion along a straight line, or linear motion. A rack is simply a straight bar with gear teeth cut in one side. When the gear turns, the rack moves along its guide rails. The rack transmits information by changing position along its longitudinal axis. The change in position of the rack is a measure of the linear distance it has moved from its designated zero position. The rack can also be made to position a gear and thus to convert linear motion into rotary motion.

Spur Gears

Spur gears are used to transmit rotary motion between parallel shafts. These gears have either straight teeth or helical teeth, as illustrated in figure 3–2.

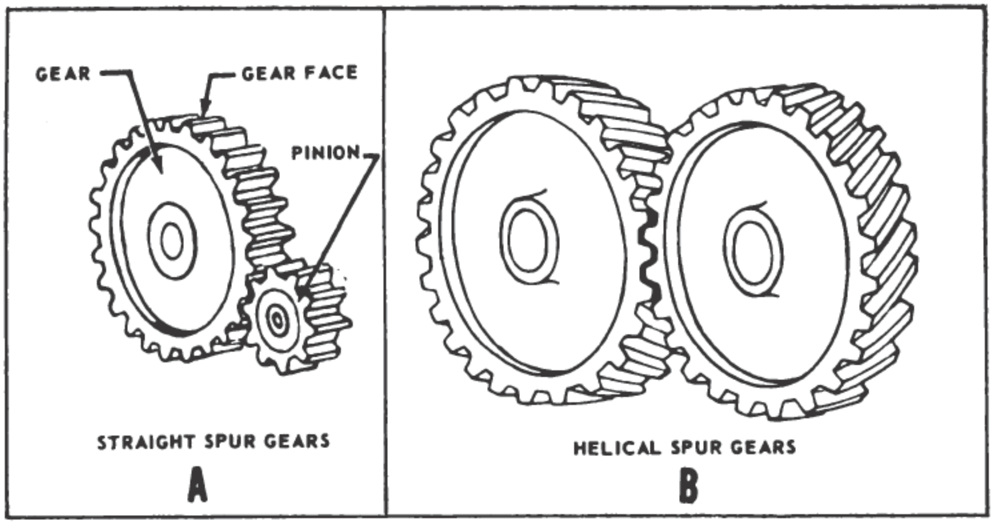


Figure 3—2.—Spur gears.

In the STRAIGHT SPUR GEAR (fig. 3–2,A) the teeth are cut parallel to the axis of rotation. The faces of the teeth are not flat but have the form of an involute curve. The entire length of one tooth comes into contact with its mating-gear tooth along the line of tangency between the two faces. In this way rolling action occurs between the two surfaces as the gear teeth come into mesh and sliding friction is eliminated.

In the HELICAL SPUR GEAR (fig. 3–2,B) the teeth are cut with a lead angle across the face of the gear blank to form a cylindrical helix like the thread of a screw. One end of each tooth lies ahead of the other end; that is, each tooth has a leading end and a trailing end. Therefore the teeth are cut at some angle, other than parallel, to the axis of gear rotation. The leading ends of two teeth come into line contact at one time with the mating gear and move progressively across the face of the gear until the trailing ends of the teeth are in contact. Because of the lead-angle cut of the teeth, more than one tooth is in mesh at a time. This meshing action results in quiet, smooth operation.

Bevel Gears

Bevel gears are used to transmit motion between two or more shafts that are not parallel. In other words, they

can be designed to operate at any desired angle between the two shafts. By the use of bevel gears, one shaft can be made to drive several shafts mounted at different angles.

Bevel gears have either straight teeth or helical teeth, as illustrated in figure 3–3. The teeth of the STRAIGHT BEVEL GEAR (fig. 3–3,A) are cut straight across the face of the gear tapering toward the axis of rotation. As in the straight spur gear, the entire length of one tooth comes into line contact at one time with the mating gear.

The teeth of the SPIRAL BEVEL GEAR (fig. 3–3,B) are cut with a lead angle across the face of the gear blank. As in the straight bevel gear the teeth taper toward the axis of rotation. As in the helical spur gear, the teeth have leading and trailing ends and have more than one tooth in mesh at one time with the mating gear. If two bevel

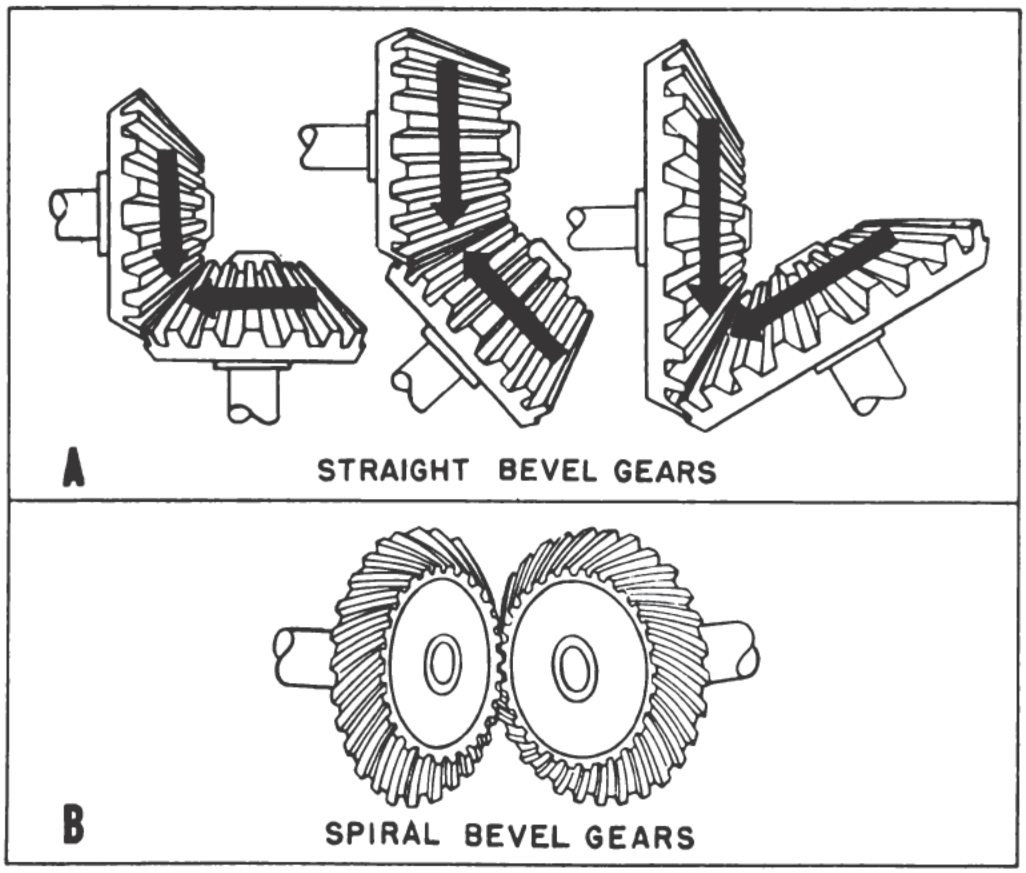


Figure 3—3.—Bevel gears.

gears are of equal size and their shafts are at right angles to each other, they are called MITER GEARS.

Internal Gear

Internal gears have their teeth cut on the inside circumference of a ring parallel with the axis of rotation, as illustrated in figure 3–4. In order to have an internal gear mesh with an external gear or pinion, the axis of the external gear is parallel to, but offset from, the axis of the internal gear. Either the external or the internal gear can be the driving gear.

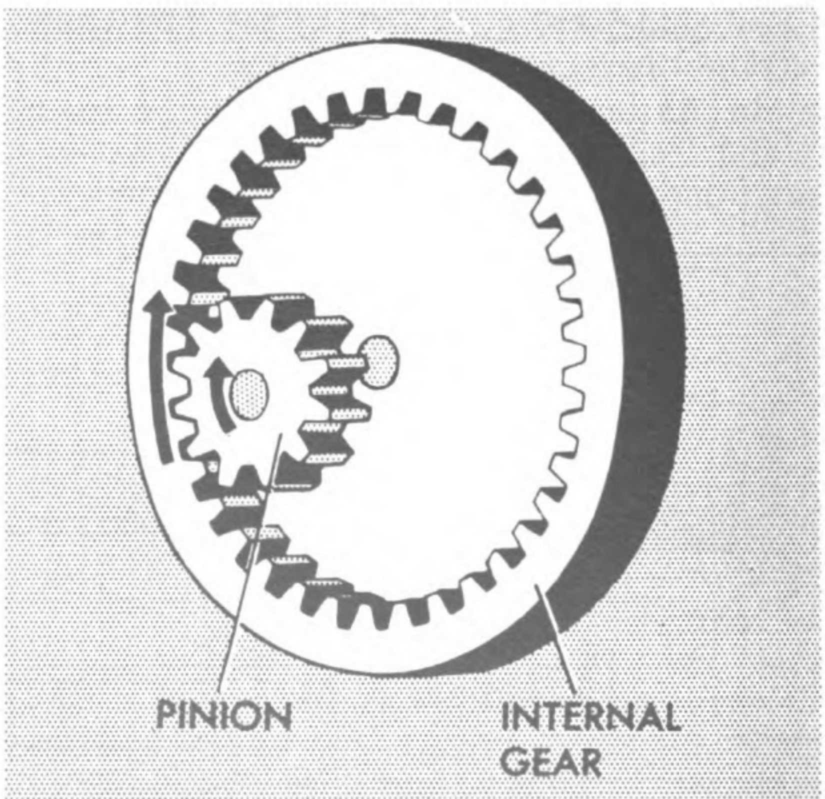


Figure 3—4.—Internal gear.

Worm and Worm Wheel

A worm and worm wheel consists of a helical screw called the WORM and a straight spur gear called the WORM WHEEL, as illustrated in figure 3–5. The helical screw thread of the ordinary worm is a groove around the body of the screw that makes a constant angle with the axis

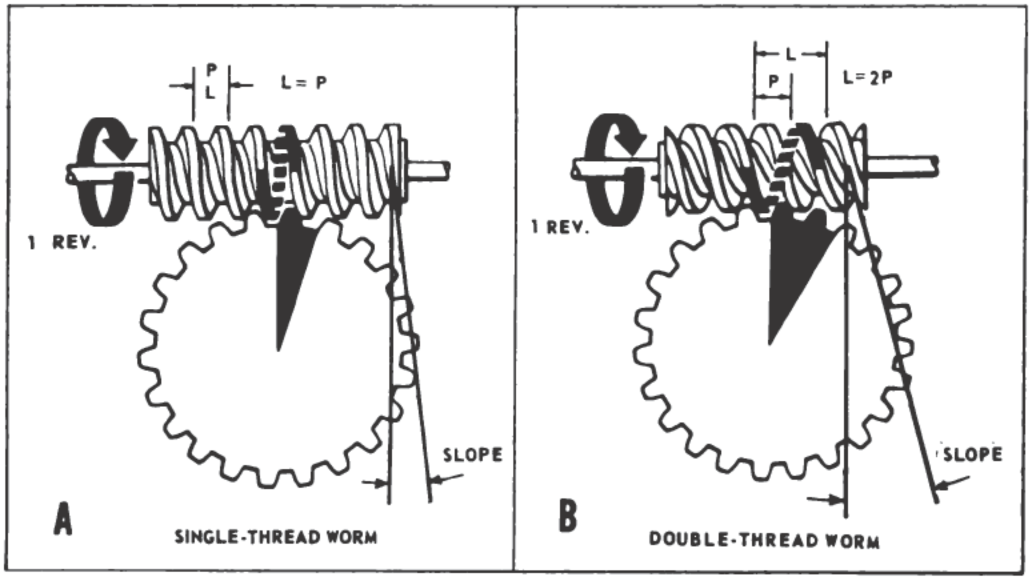


Figure 3—5.—Worm and worm wheel.

of the cylinder. The worm wheel is a straight spur gear. The worm usually drives the worm wheel. However, if the worm wheel is to drive the worm, the slope of the worm threads must be between 45° and 60° to prevent the gears from locking.

The amount that the worm wheel turns for one turn of the worm is always equal to the LEAD. The lead, L, is the distance between corresponding points on the same thread, irrespective of the number of threads, as indicated in figure 3–5. In a SINGLE THREAD WORM there is only one groove running around the body of the cylinder and the lead is equal to the pitch, P. The pitch is the distance between corresponding points on adjacent grooves, for example, from the center of the top of one thread to the center of the top of the next thread. In a DOUBLE-THREAD WORM there are two grooves running around the body of the cylinder and the lead is the width of two teeth. Hence, a single-thread worm (fig. 3–5,A) advances its worm wheel one tooth for each revolution of the worm, and a double-thread worm (fig. 3–5,B) advances its worm wheel two teeth for each revolution of the worm. The black sectors denote the amount that the

worm wheels are turned by one revolution of the worms respectively for a single-thread worm and a double-thread worm. Thus, in a single-thread worm the lead is equal to the pitch. In a double-thread worm the lead is equal to twice the pitch and in a triple-thread worm the lead is equal to three times the pitch.

Worms are used generally where great reductions in speed are required.

Gear Ratios

The ratio between the number of teeth on the driving gear and the number of teeth on the driven gear is called the GEAR RATIO. If a driving gear has 24 teeth and the driven gear has 12 teeth, 1 revolution of the driving gear turns the driven gear two revolutions. Thus, the gear ratio is 2 to 1 and the driven gear rotates twice as fast as the driving gear. If the driving gear has 10 teeth and the driven gear has 60 teeth, the gear ratio is 1 to 6 and the driving gear completes six revolutions for each revolution of the driven gear.

Gear ratios for spur gears, bevel gears, and internal gears can be determined by one of three methods—

1. $\text{gear ratio} = \dfrac{\text{number of teeth on driving gear}}{\text{number of teeth on driven gear}}$;

2. $\text{gear ratio} = \dfrac{\text{circumference of driving gear}}{\text{circumference of driven gear}}$;

3. $\text{gear ratio} = \dfrac{\text{diameter of driving gear}}{\text{diameter of driven gear}}$.

The relative directions of rotation of meshing spur gears are shown in figure 3–6. Any two mating spur gears turn in opposite directions (fig. 3–6,A).

If a shaft is required to turn another shaft in the same direction, an IDLER GEAR must be used between the driving gear and the driven gear (fig. 3–6,B). The idler turns in a direction opposite to that of the driving gear and turns the driven gear in the same direction as the driving gear.

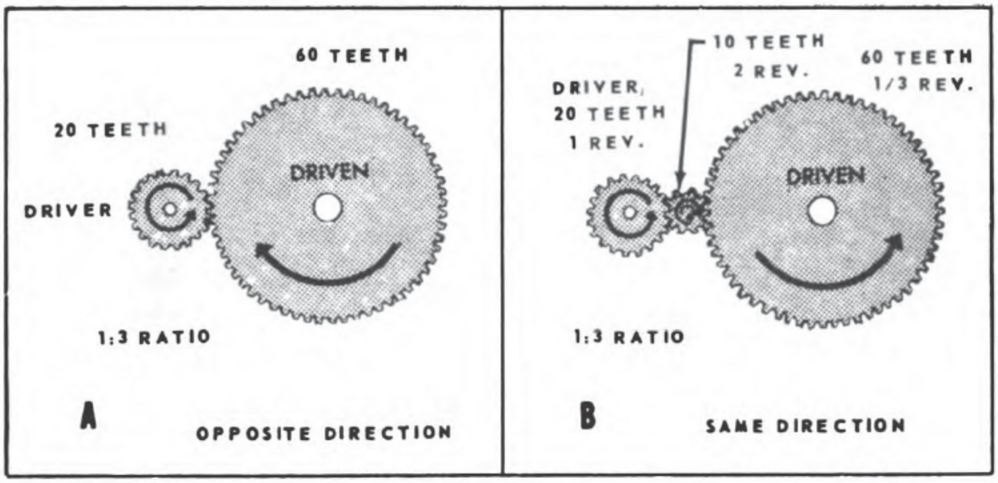


Figure 3—6.—Directions of rotation of spur gears.

An idler between two gears does not affect the gear ratio because each time the driving gear turns one tooth of the idler, the idler turns one tooth of the driven gear. If a 20-tooth pinion drives a 60-tooth gear through a 10-tooth idler (fig. 3–6,B), for each revolution of the driving pinion the idler makes two revolutions because the idler has half as many teeth as the pinion. For each revolution of the idler the driven gear turns one-sixth revolution because the driven gear has six times as many teeth as the idler. Hence, for each revolution of the driving pinion the idler makes two revolutions and the driven gear makes $2 \times 1/6$, or one-third revolution. The gear ratio is 1 to 3—the same as if the pinion had driven the gear directly.

Gear ratios between worms and worm wheels are determined by dividing the number of threads on the worm by the number of teeth on the worm wheel because each thread of the worm moves one tooth of the worm wheel a distance equal to the lead—

$$\text{gear ratio} = \frac{\text{number of threads on worm}}{\text{number of teeth on worm wheel}}$$

If a single-thread worm drives a 100-tooth worm wheel, the gear ratio is 1 to 100. Thus, the worm makes 100

revolutions for 1 revolution of the worm wheel. If the worm is triple-threaded, the gear ratio is 3 to 100 and the worm makes 100 revolutions for three revolutions of the worm wheel.

The ratio of the speed of the driving gear to the speed of the driven gear is called the SPEED RATIO. Gear ratio and speed ratio are the inverse of each other; that is, if two mating gears have a gear ratio of 2 to 1, the speed ratio is 1 to 2.

Gear ratios are often used to change shaft values. Various electrical followup devices operate efficiently only at comparatively high speeds with low shaft values. When a signal is received by means of such a device, it is customary to reduce the speed and increase the shaft value of the signal received to match the values required by the associated mechanisms by means of gear ratios. Similarly, when a high-value signal is sent from the mechanism by means of a transmitter having a low shaft value, the shaft value is usually reduced by means of a gear ratio.

Gear Trains

When several gears are meshed together as shown in figure 3–7, they constitute a GEAR TRAIN. The ratio between the driving gear at one end and the driven gear at

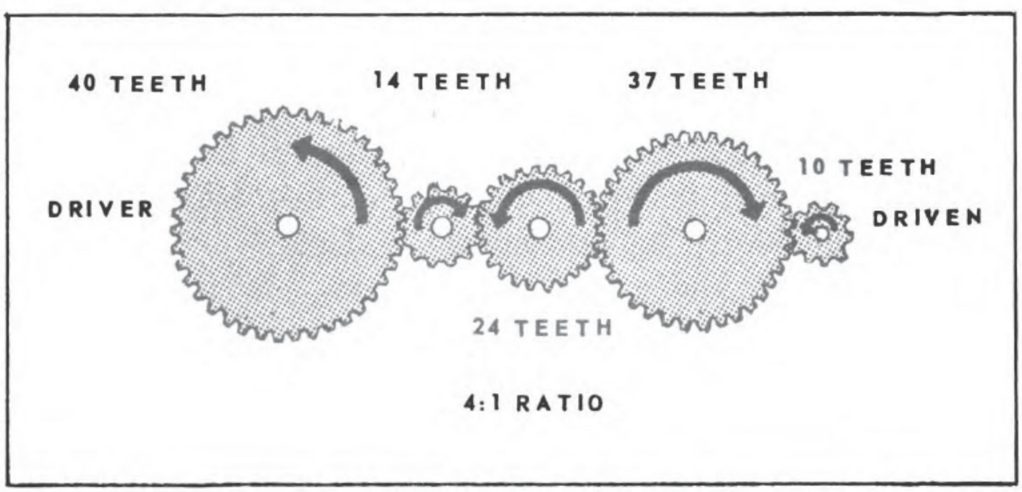


Figure 3—7.—Gear train.

the other end of such a gear train is always the same as if the driving gear were meshed directly with the driven gear, because in such cases, the intermittent gears are idlers.

When a large increase in the number of revolutions is required between two shafts, it is better to obtain the increase in several steps rather than in a single step. Suppose a 12-to-1 ratio is needed between two shafts. A driving gear 12 times as large as the pinion would be required to obtain this increase in one step. Such a large driving gear would not be practical because it would be cumbersome and would waste valuable space.

This 12-to-1 ratio is best obtained in several steps using intermediate shafts, each of which carries two gears of different size, as shown in figure 3–8.

Gears A and B have a 2-to-1 gear ratio. For each turn of driver A, gear B makes two revolutions. Gear C also makes two revolutions for one revolution of driver A because gears B and C are on the same shaft. Gears C and D have a 3-to-1 gear ratio. Thus, gear D makes 3 revolutions for each turn of gear C, or 6 revolutions (3×2) for each turn of driver A. Because gears E and F have a 2-to-1 gear ratio, gear F makes two revolutions for each turn of gear E, or 12 revolutions (2×6) for each turn of driving gear A. The gear ratio between gears A and F is, therefore, 12 to 1. This ratio is obtained without the use of large gears. To determine the ratio of this train

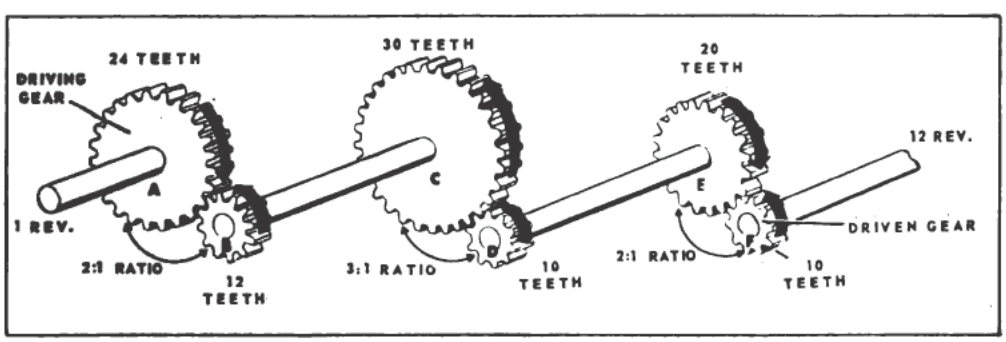


Figure 3—8.—Gear train with intermediate shafts.

of gears, multiply together the gear ratios between each pair of gears.

DIFFERENTIALS

A differential is a gear mechanism that performs addition or subtraction with the inputs from two shafts and translates the total or difference through a third shaft. It operates continuously and accurately, producing a continuous series of resultants from inputs of a fraction of a revolution to any number of shaft revolutions.

The types of differentials generally used in I. C. instruments are (1) bevel-gear differentials, (2) jewel-gear differentials, and (3) internal-gear differentials.

Bevel-Gear Differential

A bevel-gear differential is shown in figure 3–9. Four bevel gears are meshed together and grouped around the center of the mechanism. These four gears and the spider shaft are the heart of the differential. The left and right bevel gears are called END GEARS, and the top

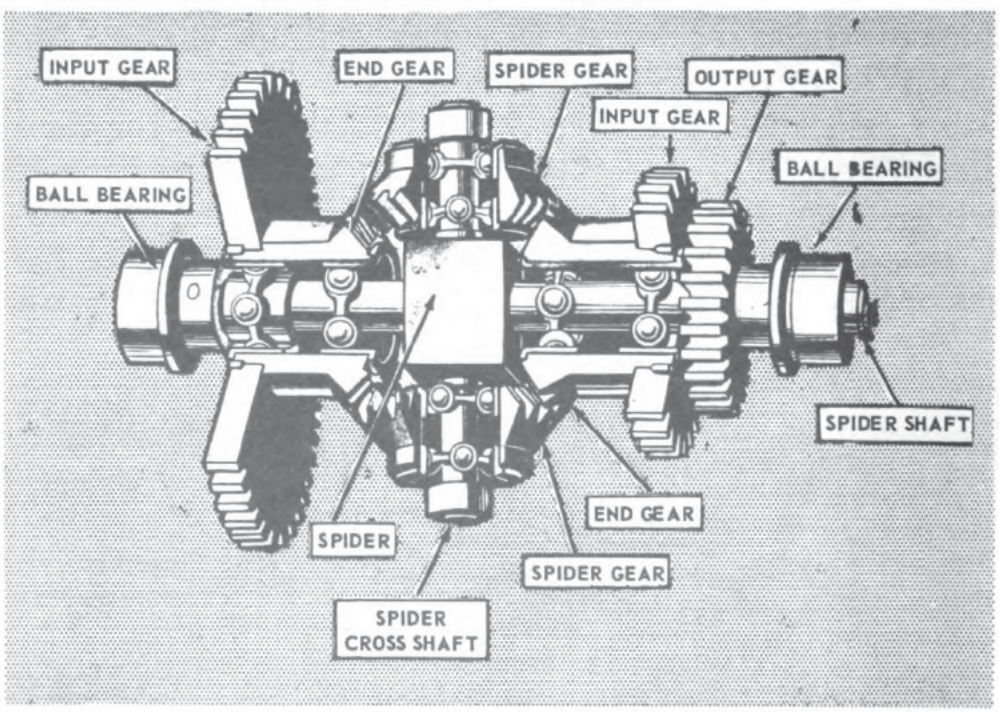


Figure 3—9.—Bevel-gear differential.

and bottom bevel gears are called SPIDER GEARS. The spider gears are meshed with the end gears.

The cross shaft and spider gears together are called the SPIDER and the long shaft is called the SPIDER SHAFT. All four of the bevel gears are free to rotate on precision bearings.

The three spur gears are used to connect the two end gears and the spider shaft to other mechanisms. Each of the two input gears is attached to an end gear. An input gear and an end gear together are called a SIDE of the differential. The output gear is pinned to the spider shaft and is the only gear in the mechanism that is pinned directly to a shaft.

The two end gears in figure 3–9 are positioned by the input shafts, which represent quantities to be added or subtracted. The spider gears do the actual adding and subtracting. They follow the rotation of the two end gears, turning the spider the number of revolutions that is proportional to the sum of, or the difference between, the revolutions of the end gears.

If the left side of the differential is rotated while the right side remains stationary, the rotating end gear turns and rolls the spider gears on the stationary end gear. This motion rotates the spider in the same direction as the input and thereby turns the output shaft with it. The output shaft turns the number of revolutions that is proportional to the input.

If the right side of the differential is now rotated and the left side held stationary, the same action occurs. The spider gears again turn and roll on the stationary end gear, turning the spider in the direction of the moving side. The output shaft turns the number of revolutions that is proportional to the input.

Thus if both sides of the differential are turned in the same direction at the same time, the spider will be turned by both sides at once. The output will be proportional to the sum of the two inputs. However, the spider is not

the whole sum of the two inputs. Because the spider gears are free to roll between the end gears, the spider actually makes only half as many revolutions as the sum of or the difference between the revolutions of the end gears.

This principle is easily demonstrated if a cylindrical drinking glass turned on its side is rolled along a table top by a ruler pushed across its upper side. The glass will roll only half as far as the ruler travels. The spider gears in the differential roll against the end gears in a similar manner. Hence, a differential produces only half the answer in adding or subtracting the revolution of its input gears.

In order to produce the correct (whole) answer, 2-to-1 ratio gears are required between the spider shaft (differential output) and the input shaft of the next mechanism (fig. 3–10). This gear ratio doubles the output to give the whole answer. Actually the 2-to-1 ratio is seldom obtained in differential gearing in any computer for design reasons. However, for the sake of clarity it is assumed here that all differentials have 2-to-1 gearing and that the final output is complete and correct.

When both inputs of a differential rotate in the same direction, the differential ADDS (fig. 3–10). If both sides of the differential turn in the same direction for the same number of revolutions, the spider gears do not rotate on the cross shaft. Instead, they maintain a fixed position between the end gears and the cross shaft rotates end over end with them, carrying the spider around to a new position. The rotations of the spider and its shaft are equal to half the sum of the revolutions to the two inputs—that is, the spider shaft rotates exactly the same number of revolutions as each individual input when they are equal and turn in the same direction ($X + X$ in fig. 3–10,A).

If one side of the differential makes more revolutions than the other, the spider cross shaft and gears are carried around end over end by both end gears. At the same

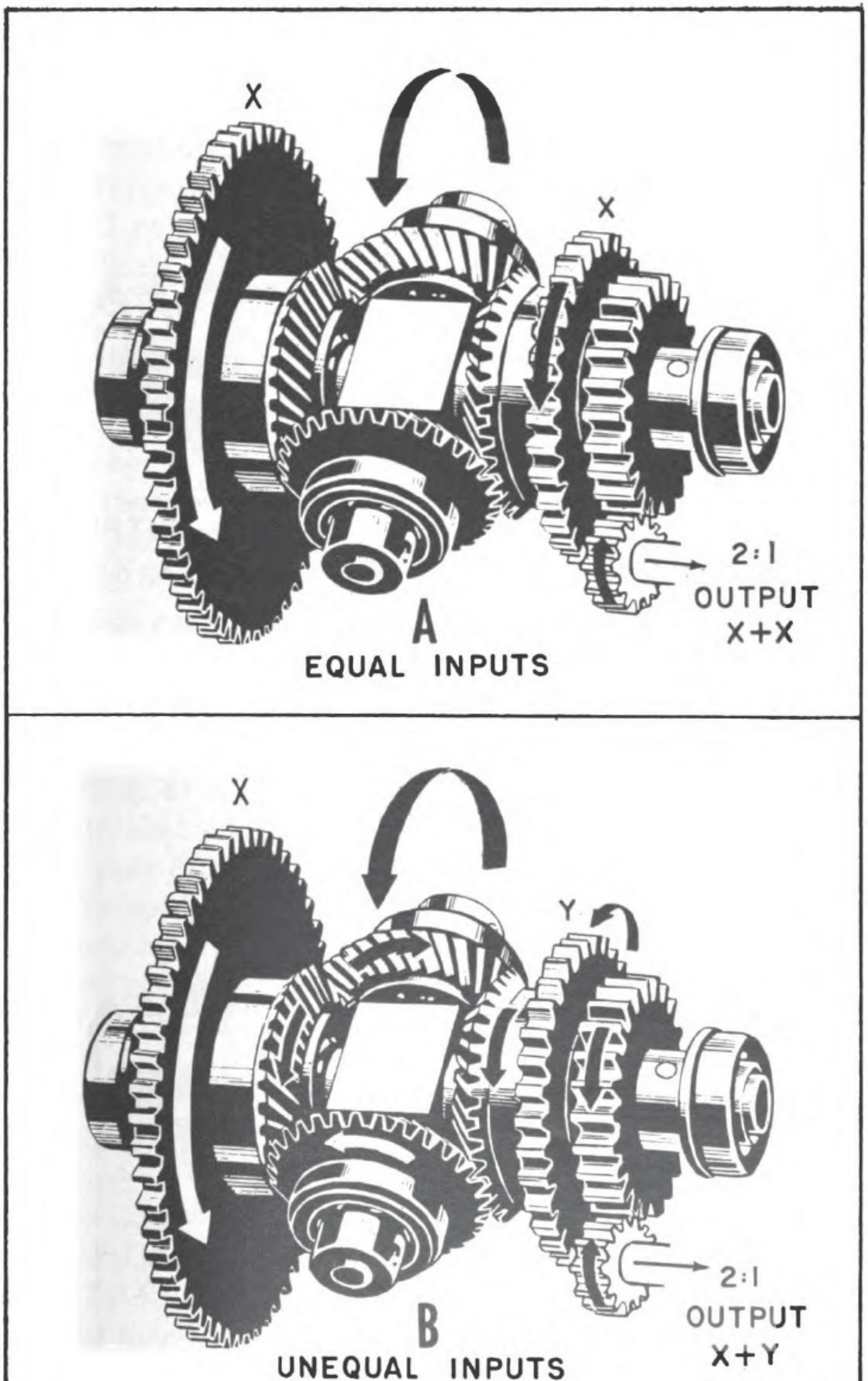


Figure 3—10.—Differential adding.

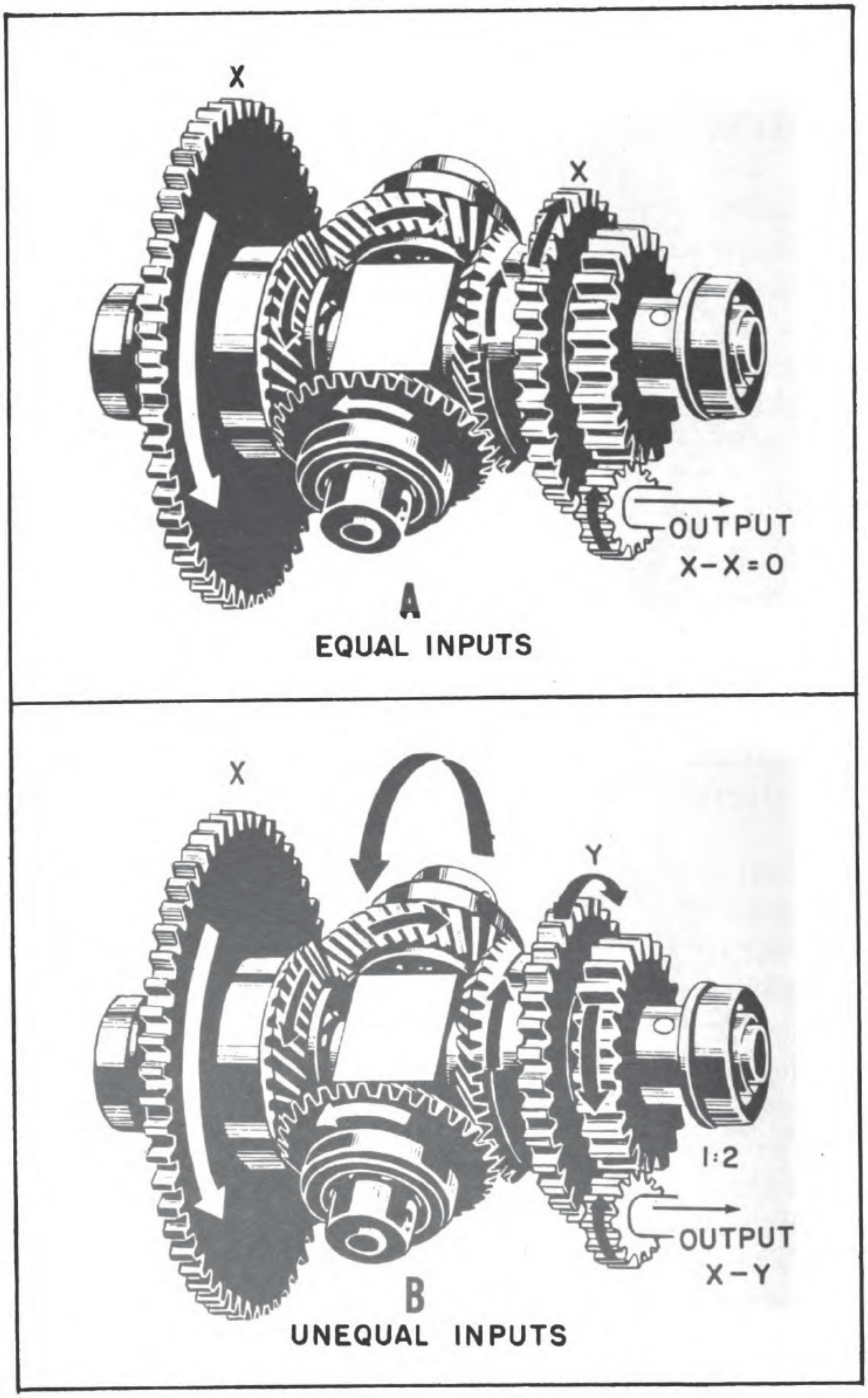


Figure 3—11.—Differential subtracting.

time, the spider gears roll on the end gear that is turning the fewer number of revolutions. The spider shaft turns half the sum of the revolutions of the two inputs when they turn in the same direction ($X + Y$ in fig. 3–10,B).

The differential SUBTRACTS when the two inputs of a differential rotate in opposite directions (fig. 3–11). If the two inputs turn in opposite directions and have the same number of revolutions, the spider gears will roll between the end gears without moving the spider cross shaft. The output is zero ($X - X = 0$ in fig. 3–11,A).

If the two inputs turn in opposite directions for an unequal number of revolutions, the spider gears roll on the end gear that turns the fewer revolutions, rotating the spider in the direction of the input that is turning the greater number of revolutions. The motion of the spider shaft in this case is equal to half the difference between the revolutions of the two inputs ($X - Y$ in fig. 3–11,B).

Jewel-Gear Differential

The action of a jewel-gear differential (fig. 3–12) is identical to that of the bevel-gear differential. However, the jewel-gear differential uses spur gears instead of bevel gears. The spider is a case that encloses the two end gears and the two spider gears. The two spider gears mesh together, and each meshes with one of the end gears. The shafts of the spider gears turn on jewel bearings set into the spider, so that the spider gears travel around with the spider just as in the bevel-gear differential. Each side of the jewel-gear differential consists of a spur end gear and a side shaft.

The jewel-gear differential is designed to operate only small mechanisms with light loads, such as electrical contacts. Most of the shafts are mounted on jewel bearings so that the mechanism is sensitive to very small and very light inputs, and runs very smoothly. It is used in follow-up controls where the signals come from receiver rotors and where the exact amount of turning is very important.

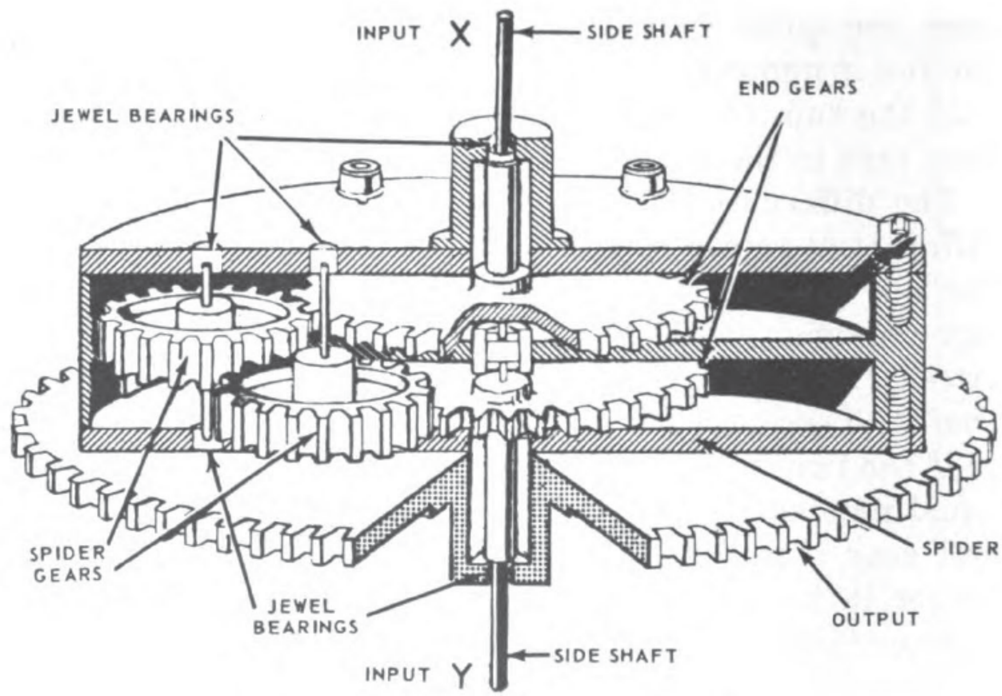


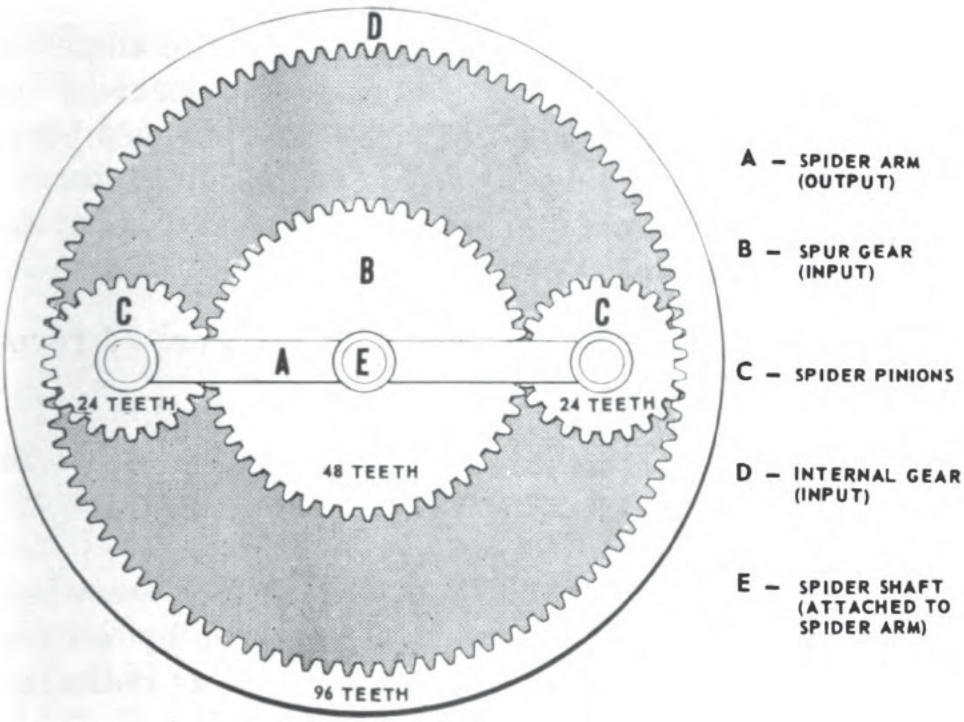
Figure 3—12.—Jewel-gear differential.

Internal-Gear Differential

An internal-gear differential is shown in figure 3–13. The principle and use of this type of differential are the same as those of the bevel-gear and jewel-gear types. The internal-gear differential consists of an internal gear; a spur gear; two spider pinions; and a spider arm. The spur gear receives one input and the internal gear receives the other input. The output shaft of the differential is attached to the spider arm.

The INTERNAL GEAR, D, is a large ring with the teeth cut on its inside circumference. The SPUR GEAR, B, is mounted in the center of the internal gear and meshes with the two SPIDER PINIONS, C, which in turn mesh with the internal gear. The spider pinions, C, are connected together by the SPIDER ARM, A, which is pivoted to rotate about, but is not rigidly fixed to the axis of the spur gear, B. The OUTPUT SHAFT of the internal-gear differential is attached to the center of the spider arm, A.

In order to understand the operation of this differential



	A	B	C	D
GEARS LOCKED ARM ROTATED	+ 1	+ 1	+ 1	+ 1
ARM LOCKED GEARS ROTATED	0	1 x 96/24 x 24/48 = +2	−1 x 96/24 = −4	− 1
TOTAL	+ 1	+ 3	− 3	0

Figure 3—13.—Internal-gear differential.

consider the following example. Spider arm A is attached to the output shaft. Spur gear B has 48 teeth and receives one input. Spider pinions C each have 24 teeth and mesh with spur gear B and internal gear D. Internal gear D has 96 teeth. If spur gear B is turned clockwise one revolution while internal gear D is held stationary, spider arm A will follow clockwise through 1/3 revolution. This action may be explained by making certain assumptions.

First, assume that all gears are locked and spider arm A is rotated clockwise 1 complete turn. Because all gears are locked, each gear makes 1 complete turn clockwise as indicated in the table (fig. 3–13) by +1 for all members.

Next, assume that spider arm A is locked, and internal gear D is rotated 1 complete turn counterclockwise as indicated in the table by —1 for gear D and by 0 for arm A. Pinion C rotates counterclockwise $-1 \times \frac{96}{24}$, or —4 revolutions. Spur gear B rotates clockwise $+1 \times \frac{96}{24} \times \frac{24}{48}$, or +2 revolutions.

The total number of revolutions of each member when internal gear D is stationary is determined by adding algebraically the two components of motion, as indicated in the table. In the first condition, internal gear D rotated 1 revolution clockwise; whereas in the second condition it rotated 1 revolution counterclockwise, resulting in a net total of zero. Hence, this action fulfills the requirement that D remain stationary. Spider pinion C rotates +1 —4, or —3 revolutions. Spur gear B rotates +1 +2, or +3 revolutions and spider arm A rotates +1 +0, or +1 revolution. Thus, one clockwise revolution of spider arm A causes spur gear B to rotate 3 revolutions in the same direction. Conversely, 1 revolution of spur gear B causes arm A to turn in the same direction ⅓ revolution for the condition that internal gear D remains stationary.

If spider arm A is held stationary and internal gear D is rotated 1 revolution counterclockwise, spider pinion C rotates $\frac{96}{24} \times 1$, or 4 revolutions in the same direction. Spur gear B rotates in the opposite direction $\frac{24}{48} \times 4$, or 2 revolutions. Thus, the speed ratio of B to D is 2 to 1 when arm A is stationary. If this speed ratio is not

maintained, arm A will turn in the direction of the faster moving gear.

The laws that apply to the speed of the spider when there is a difference in speed of the driving motors, are not the same as for bevel-gear and jewel-gear differentials; that is, the spider follows the faster member but not at half the difference in speed between the two.

SERVOMOTORS

The outputs of many mechanisms in I. C. instruments are not powerful enough to position heavily loaded shafts. Therefore, these outputs are used to control the action of SERVOMOTORS, or FOLLOWUP MOTORS, that actually position the loads.

Servomotors and followup motors are identical, although they are often associated respectively with F. C. and I. C. installations. However, these terms are used interchangeably throughout this training course. These motors are designed for operation on either d-c or a-c service, depending upon the type of control incorporated in the particular servomechanism or followup system.

D-c servomotors are of the series and shunt types; whereas, a-c servomotors are of the single-phase and two-phase induction types. The most common types employed in I. C. instruments are the single-phase capacitor and shaded-pole motors (fig. 3–14). The principles of all these motors are explained in the training course, *I. C. Electrician 3*, NavPers 10555.

Capacitor Motor

The capacitor motor is similar to the split-phase motor, except that a capacitor is connected in series with one or the other stator winding (fig. 3–14,A), depending upon the direction or rotation of the rotor. The capacitor action determines the direction of rotation by causing the current in the winding to which it is connected to lead the current in the other winding.

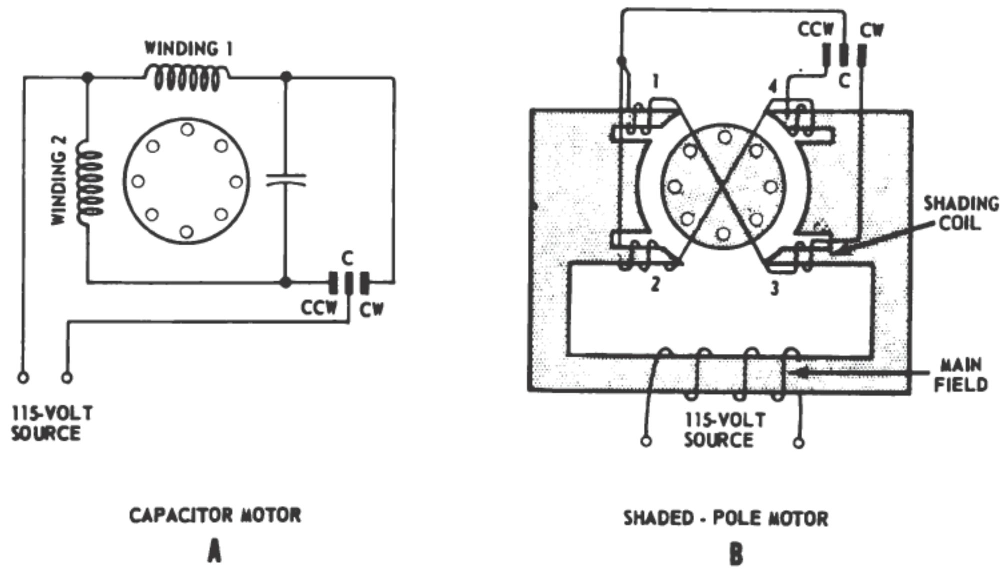


Figure 3—14.—Servomotors.

Stator windings 1 and 2 are connected respectively to outer contacts CW and CCW of the followup control. One side of the 115-volt 60-cycle supply is connected to inner contact C of the followup control and the other side is connected to the other ends of windings 1 and 2. The followup control acts to bring the center contact, C, against either the CW or CCW contact and thus determines the direction of rotation of the capacitor type servomotor.

When the followup control completes the circuit through outer contact CW, the 115-volt supply is connected directly across winding 1 in parallel with the series combination of winding 2 and the capacitor. The capacitor action causes the current in winding 2 to lead the current in winding 1, resulting in rotation of the rotor in a clockwise direction.

When the followup control completes the circuit through outer contact CCW, the 115-volt supply is connected directly across winding 2 in parallel with the series combination of winding 1 and the capacitor. Under this condition, current in winding 1 leads the current in winding 2, and the rotor turns in a counterclockwise direction.

If either the CW or the CCW contacts are closed, the

motor will run until they are opened, at which time the motor stops. All servomotors are similar in two respects —(1) they are required to start and stop quickly and (2) they are electrically reversible.

Shaded-Pole Motor

The shaded-pole motor consists of a squirrel-cage rotor and a stator having two salient poles. The salient poles have two split sections each of which is provided with shading coils (fig. 3–14,B). A single-phase stator winding provides the primary component of magnetic flux for the motor.

The main field is normally energized. The motor is started by connecting one pair of diametrically opposite shading coils in a closed series circuit. The motor is stopped by open-circuiting the shading coils and is reversed by connecting the diametrically opposite pair of shading coils in a closed series circuit. The motor remains idle without harmful effects with the shading coils open-circuited and the main field energized.

The followup control acts to bring contact C against either the CW or CCW contact. When contact C is against contact CW, the motor runs in a clockwise direction. Conversely, when contact C is against contact CCW, the motor runs in a counterclockwise direction.

CAMS

A cam is a machine element with an irregular surface or groove shaped to convert rotary motion into special or irregular motion in a second part called a FOLLOWER. The follower is usually returned to its normal position by a spring.

Cams have a variety of curved surfaces such as grooves, ridges, or contours. The curved surface is positioned by the input. Each point on the curved surface represents a different output value. The follower rides on the curved surface and reproduces the irregularity as a reciprocating motion.

As the input shaft turns at any given point of the cam, the follower is pushed by the curved surface into a position that registers the output value for that point of the cam. Some common types of cams are the constant-lead cam, reciprocal cam, secant cam, square cam, heart cam, and indented cam. The heart cam and the indented cam are the types most frequently used as components of followup systems in many I. C. instruments.

Heart Cam

The heart cam is often used in synchro followup control systems to provide a flexible coupling between the outer and center contacts of an electric switch. This device (fig. 3–15) consists of a heart-shaped plate, two outer contacts, a center contact, a follower roller, and a follower spring.

The outer contacts CW and CCW are carried on an arm that is fixed to the heart cam. The heart cam is ball-bearing mounted on the synchro-receiver rotor shaft so that the arm and cam turn freely as a unit. The center contact, C, is carried on a separate stationary arm. The two outer contacts and the center contact control the starting, stopping, and reversing of the servomotor that drives the shaft load.

The follower arm, with the follower roller and the follower spring, is keyed to the end of the synchro-receiver rotor shaft. The follower spring keeps the follower roller seated firmly in the valley of the heart cam (fig. 3–15, A).

Whenever an incoming signal from the synchro transmitter causes the synchro-receiver rotor to turn, the follower arm must turn because it is keyed to the rotor shaft. As the follower arm turns, the follower roller is pulled around. The follower roller, being firmly seated in the valley of the heart cam, pulls the cam around. When the heart cam is rotated, an outer contact is brought against the center contact, and the servomotor starts to drive (fig. 3–15, B)

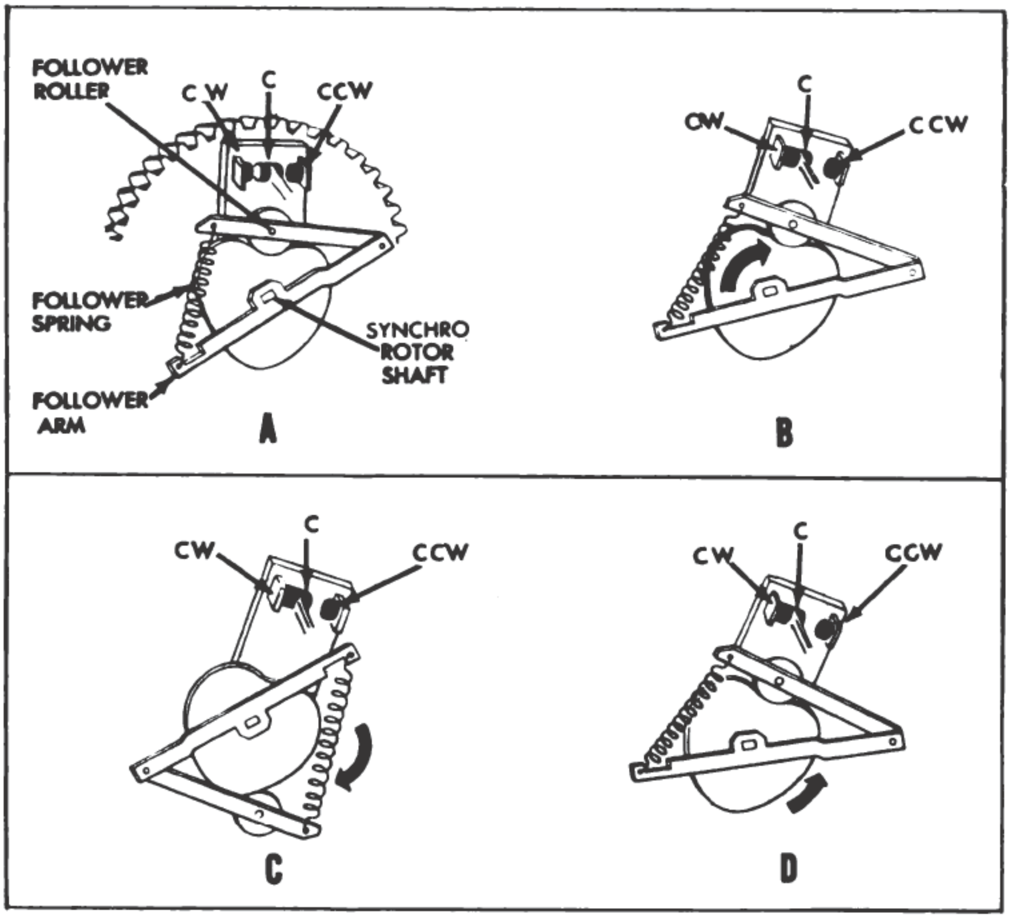


Figure 3—15.—Operation of a heart cam.

As the signal continues to come from the synchro transmitter faster than the servomotor can drive, the rotor of the synchro receiver continues to turn and to carry the follower arm around with it. The follower roller is now forced out of the valley and rides around the heart cam, pressed to its side by the action of the follower spring (fig. 3–15, C).

Although an outer contact is held firmly against the center contact, the synchro-receiver rotor is still free to turn, without disturbing the contacts. If the followup fails to function, the follower continues to rotate around the heart cam until the response signal opens the contacts. This action provides a flexible coupling between the switch contacts which prevents damage to them in the event of power failure to the servomotor.

As the servomotor turns the load into correspondence with the input, the response shaft drives the bearing-mounted synchro-receiver stator backward (fig. 3–15, D). This action turns the rotor backward without altering the input signal because it is locked magnetically with the stator. Thus the rotor transmits a backward torque to the heart cam that opens the electrical contacts and stops the servomotor. The bearing-mounted synchro receiver is described in detail later in this chapter.

Indented Cam

The indented cam is also used to provide another type of followup control for the servomotor. This device (fig. 3–16) consists of an indented plate, a phenolic disk, a rocker contact assembly with roller, two outer contacts, and a center contact.

The phenolic disk holds the rocker assembly. The rocker is pivoted at its center. Two contact arms, supported by springs, are attached to the bottom of the rocker. The disk has two outer contacts located above the contact arms. When the rocker is tilted in one direction or the other, the contact arms can touch the outer contacts.

Three slip rings are mounted on the back of the disk. One slip ring is connected to the rocker assembly and the center contact, C. The other two slip rings are connected to the outer contacts, CW and CCW. Brushes on the slip rings connect the control for the servomotor to the rocker assembly.

The indented cam is mounted on a controlling shaft, which is in line with the shaft of the phenolic disk. The roller on the bottom of the rocker rides in the indent of the cam. When the roller on the rocker is in the center of the indent, all contacts are open and the servomotor is stationary (fig. 3–16, A). When the indented cam is turned clockwise, the rocker tilts, closing one pair of contacts and causes the servomotor to drive the disk in the same direction (fig. 3–16, B). Conversely, when the cam is turned

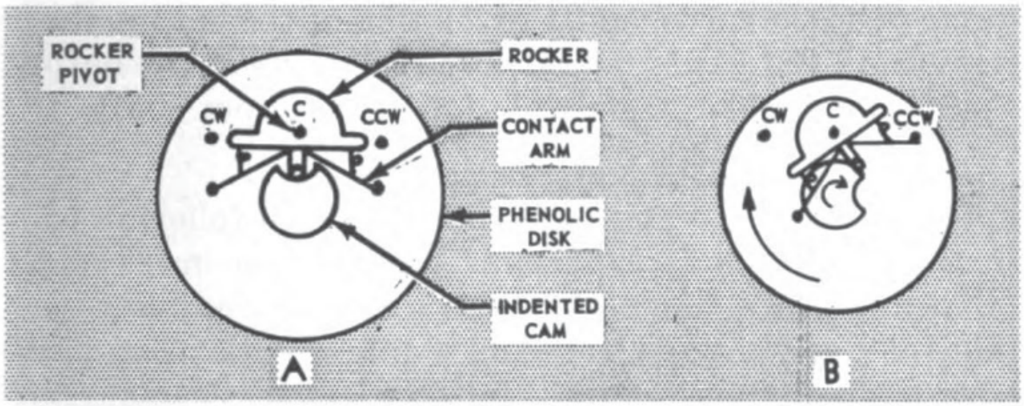


Figure 3—16.—Operation of an indented cam.

counterclockwise, the rocker tilts in the opposite direction and closes the other pair of contacts and causes the servomotor to drive the disk in the same direction. In either case, the drive continues until the roller of the rocker drops back into the indent and the contacts open. If the indented cam is turned 30° clockwise, the servomotor drives the phenolic disk until it has followed through 30°. The roller of the rocker then drops back into the indent and opens the contacts, thus stopping the servomotor. The direction in which the rocker is tilted controls the direction of drive of the phenolic disk.

FOLLOWUP CONTROLS

A SERVOMECHANISM is a combination of elements used to control a source of power. The output response of the system is fed back for comparison with the input. This feedback is the followup control of the servomechanism and the difference between these two quantities (input and feedback) is used to control the output power. When the difference between the output response and the input is zero, the output power of the servomechanism is zero. The followup control therefore regulates the action of the servomotor so that the position of the output shaft always represents the value of the quantity set into the control by the input shaft.

Suppose 1 revolution of the input shaft represents a

range of 1,000 yards, and 1 revolution of the output shaft represents 100 yards. Then 10 revolutions of the output shaft is equivalent to 1 revolution of the input shaft.

Mechanical Followup Control

The general principles of operation of all followup controls are illustrated by means of a simple mechanical followup control (fig. 3–17). This control consists essentially of a contact assembly and a differential. The principle of this type of control is represented schematically in figure 3–17, A.

The CONTACT ASSEMBLY consists of a vertical contact arm and a horizontal base plate fastened at right angles to each other and pivoted on a pin, as shown in figure 3–17, B. The control arm carries two outer contacts, CW and CCW. A stationary center contact, C, is mounted midway between the two outer contacts. A small crank arm is attached to the differential spider shaft beneath the contact assembly and carries a roller on one end.

In the normal position, the crank arm is horizontal and the base plate of the contact arm bears against the roller, by the action of a spring, to hold the contact arm in a vertical position. In this position the contacts are open and the servomotor is at a standstill.

If the crank arm turns clockwise, it rotates the outer contact arm clockwise, opposing the action of the spring. This action brings outer contact CW against center contact C and the motor drives in a clockwise direction.

Conversely, if the crank arm turns counterclockwise, the roller ceases to bear against the base plate of the outer contact arm and this arm is rotated counterclockwise by the action of the spring. This action brings outer contact CCW against center contact C and the servomotor drives in a counterclockwise direction.

The DIFFERENTIAL is used to measure the difference, or ERROR, in position between the input and output. The input is geared to one side of the differential. The servo output is used to (1) position the load and (2) drive the

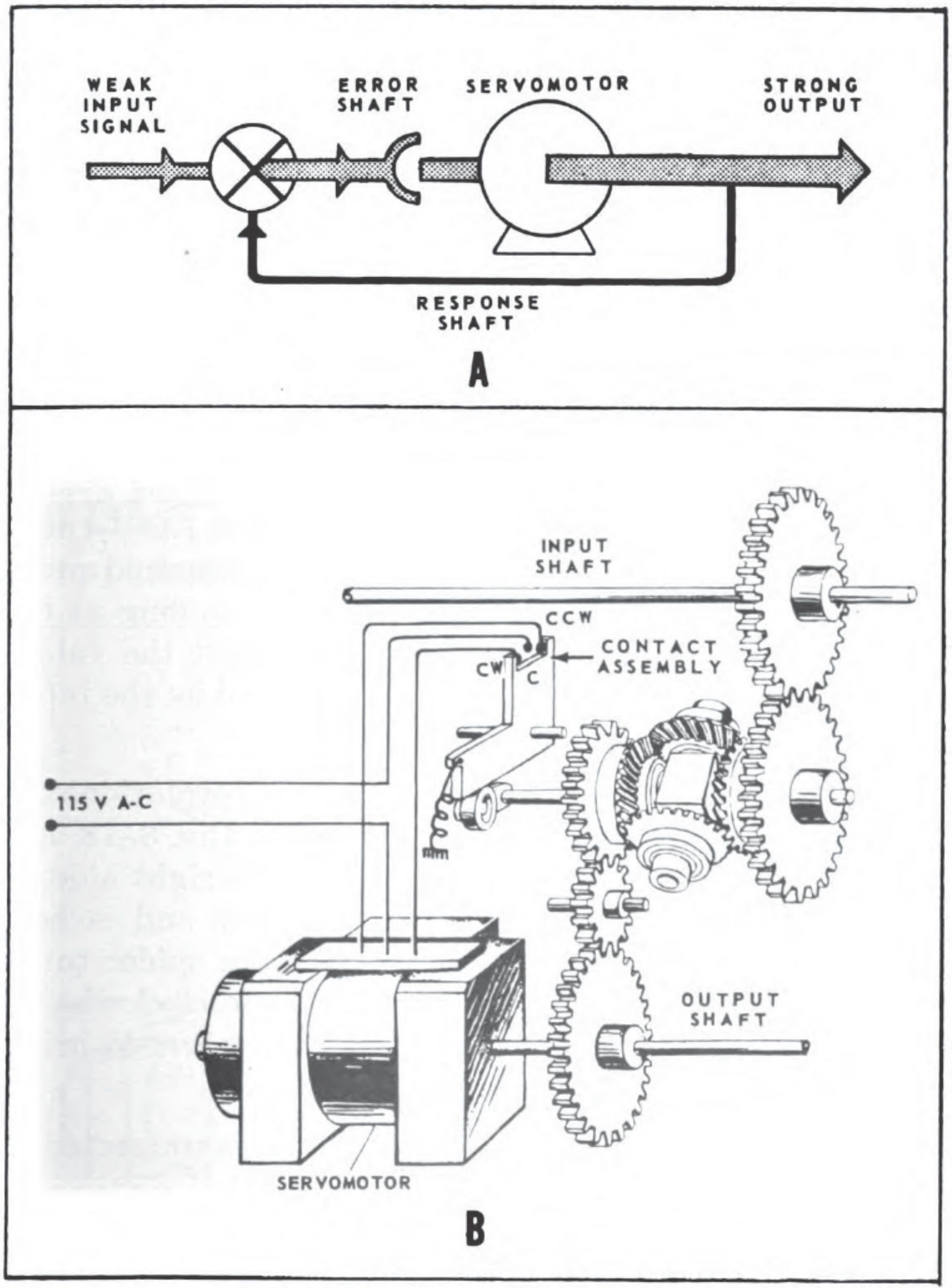


Figure 3—17.—Mechanical followup control.

other side of the differential. This action is called the servo RESPONSE.

The spider of the differential turns when there is a difference between the input and output. As the spider turns, the spider shaft operates the electrical contacts that control the operation of the servomotor so that the motor drives its side of the differential in a direction OPPOSITE to that of the input. The servomotor always drives in a direction to reduce the difference between the input and output, or error, to zero.

The OPERATION of the mechanical followup control is illustrated in figure 3–18. For simplicity, the followup control input shaft is geared to the left side of a differential by a 1-to-1 ratio and the servomotor shaft is geared to the right side of the same differential by a 1-to-1 ratio. However, this gear ratio is seldom found in actual practice. The gear ratios in the line can vary as long as the positions taken by the output shaft represent the values of the quantities set into the followup control by the input shaft.

If the input turns counterclockwise ½ revolution, the left side of the differential is driven ½ turn (fig. 3–18, A). The left side rotates the spider because the right side of the differential is geared to the servomotor and is held stationary. Because the input is ½ turn, the spider turns clockwise ¼ turn and rotates the crank arm clockwise ¼ turn. This action rotates the outer contact arm to bring contact CW against center contact C.

When contact is made, the power source is connected to the servomotor and the motor turns in a direction opposite to that of the input (fig. 3–18, B). As long as the contacts are closed the motor runs and turns the right side of the differential. This action of the servomotor constitutes the RESPONSE, which causes the spider to rotate counterclockwise toward its original position. Thus the crank arm is rotated counterclockwise toward its original

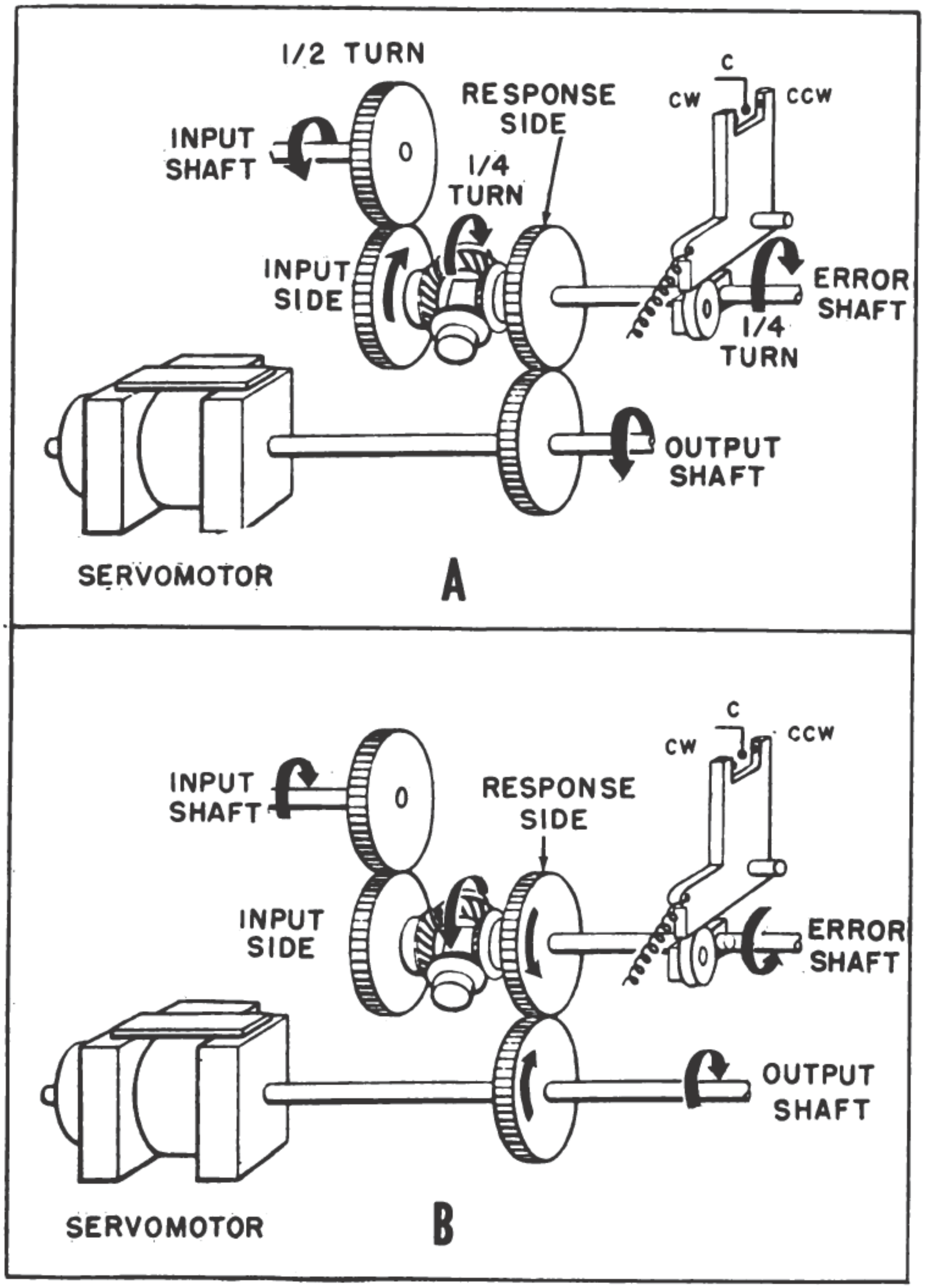


Figure 3—18.—Operation of a mechanical followup control.

position, and the spring pulls the outer contact arm back to its vertical position to open the contacts and stop the motor.

The crank arm is now at its starting point. It has been rotated back 1/4 turn and the spider that drives it has also been rotated back 1/4 turn. As the spider has been driven back 1/4 turn, the right, or response, side of the differential has been driven back 1/2 turn. In other words, the servomotor shaft has also rotated 1/2 turn, which is the same amount that the input shaft rotated because the motor shaft is geared to the right side of the differential by a 1-to-1 ratio. Therefore, the number of revolutions, or fractions of a revolution, of the output shaft corresponds exactly with the number of revolutions, or fractions of a revolution, of the input shaft from the servomechanism.

If the input rotates continuously, the motor contacts remain closed and the servomotor drives continuously in a direction to open the contacts. Until the servomotor has driven sufficiently to make the output equal the input, the input side of the differential is ahead of the response side. As long as the motor runs there is a difference, or error, between the input and output values. When both sides of the differential have been driven an equal amount, the output synchronizes with the input. This condition represents the point of correspondence, or zero error. At this point the switch contacts open and the motor stops.

Synchro Followup Control

In addition to mechanical followup controls, synchro receivers are commonly used as followup controls for servomotors in servomechanisms. The types of synchro followup controls are (1) single units operating at one speed and (2) two single units geared together operating at two different speeds. The two single units provide both fine and coarse control.

A single-speed synchro followup control consists essentially of a contact assembly and a bearing-mounted synchro receiver connected electrically to a synchro transmit-

ter (fig. 3–19). The receiver controls the action of the servomotor that drives the shaft load. The principle of this type of control is represented schematically in figure 3–19, A.

The contact ASSEMBLY that controls the action of the servo is similar to the contact assembly of the heart cam described previously. The two outer contacts are fixed

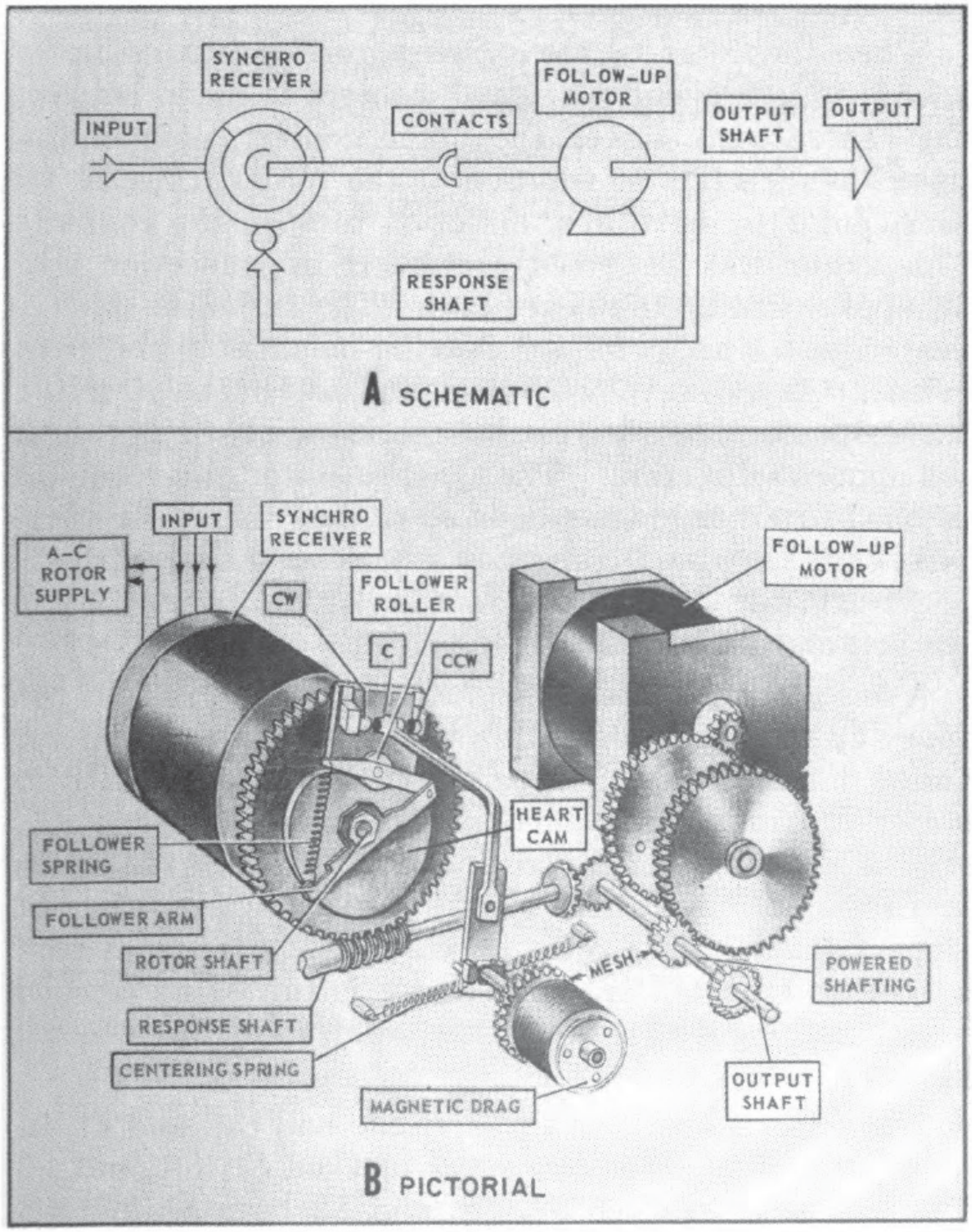


Figure 3—19.—Single-speed synchro followup control.

on an arm that can be rotated as shown in figure 3–19, B. For simplicity, the center contact arm has been considered as stationary. Actually, the center contact is mounted on an arm that can be rotated, within limits, by a MAGNETIC DRAG (fig. 3–19) geared to the servomotor. The purpose of the magnetic drag is to overcome the momentum of the servomotor and to bring the motor quickly to rest at the point of zero error.

When the rotor of the synchro receiver turns in response to a transmitted signal, contact is made between the center and one of the outer contacts (depending upon the direction of rotation of the rotor), causing the servomotor to drive in a direction to open the contacts. This action was described previously in connection with an application of the heart cam. The response shaft is geared to the stator of the bearing-mounted synchro receiver. As the servomotor turns the load in one direction, the response shaft drives the synchro-receiver stator in the opposite direction. The synchro stator and rotor are coupled together magnetically so that as the stator turns backward the rotor transmits a backward torque to the heart cam through the follower roller that finally opens the contacts and stops the motor.

A BEARING-MOUNTED SYNCHRO RECEIVER is used in this followup control to provide rotation of both the synchro stator and rotor. This type of synchro receiver with its stator bearings is mounted in hangers and is provided with a slip-ring and brush assembly for both the stator and rotor to transfer the electrical circuits from the stationary frame. The rotor is positioned by a signal from a synchro transmitter. The stator is turned by a worm wheel meshing with a worm that is driven by the response shaft.

The stator leads pass through one end cap and an insulating disk to three slip rings marked $S1$, $S2$, and $S3$. Three brushes marked $S1$, $S2$, and $S3$ bear against the respective stator slip rings.

The rotor leads are connected to two slip rings marked $R1$ and $R2$ on one end of the rotor shaft. Two brushes marked $R1$ and $R2$ bear against the respective rotor slip rings.

All five brushes are mounted on a terminal block and are connected so that signals can be transmitted to the receiver on the three stator leads while the stator is free to turn at all times. The terminal block and brush assembly are mounted on one of the stationary hangers. Single-phase 115-volt power is supplied to the rotor of the synchro-receiver in the usual way.

MECHANICAL COUNTERS

Six-Place Odometer

The six-place odometer is a six-figure counter that indicates the total revolutions of any rotating device to which it is geared. This counter consists of six drums, each containing figures from 1 through 9 to 0 on the outer surface.

The UNITS drum, or dial, is geared by a star wheel to the TENS dial; the tens dial is geared by a star wheel to the HUNDREDS dial; and so on. Thus, if a drum turns a complete revolution, the next higher drum turns one-tenth of a revolution because of the action of the star wheel. The units drum is directly connected to the driving shaft. If the driving shaft turns one revolution, the units drum turns one revolution and turns the tens drum one-tenth of a revolution. Hence, for each revolution of the driving shaft, the counter adds or subtracts 10 figures on the units drum, depending upon the direction in which the driving shaft is turned.

Eight-Place Ratchet Counter

The eight-place ratchet counter is an eight-figure counter that indicates the total revolutions of any rotating device to which it is geared. It consists of eight drums, each containing figures from 1 to 0 on the outer surface.

The units dial is geared by a star wheel to the tens dial; the tens dial is geared by a star wheel to the hundreds

dial; and so on. Unlike the six-place odometer, the units drum of the eight-place ratchet counter is not directly connected to the driving shaft. Instead, a ratchet is connected between the units drum and the driving shaft. Hence, for each revolution of the driving shaft the counter adds 1. If the driving shaft is turned in the reverse direction, the units drum backs to 0 and does not subtract any further.

FRICTION DISK AND ROLLER ASSEMBLY

Principle

If a disk is driven by a synchronous motor supplied with a controlled frequency, the disk will run at a constant speed irrespective of tolerable fluctuations of the ship's supply frequency. A roller placed in the center of the rotating disk does not turn.

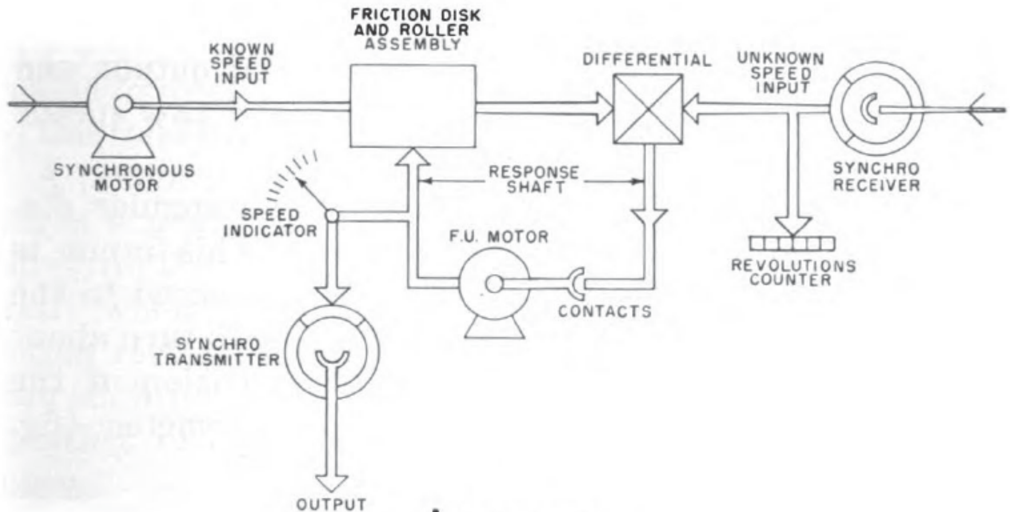
If the roller is moved out from the center of the disk, the roller turns at a speed that is proportional to the distance from the center of the disk. If the roller is moved out one-half inch from the center of the disk, the roller runs at twice the speed at which it ran when moved one-fourth inch from the center of the disk. If the position of the roller on the disk is varied, the speed of the roller is varied in direct proportion to the distance the roller is positioned from the center of the constant-speed disk.

Application

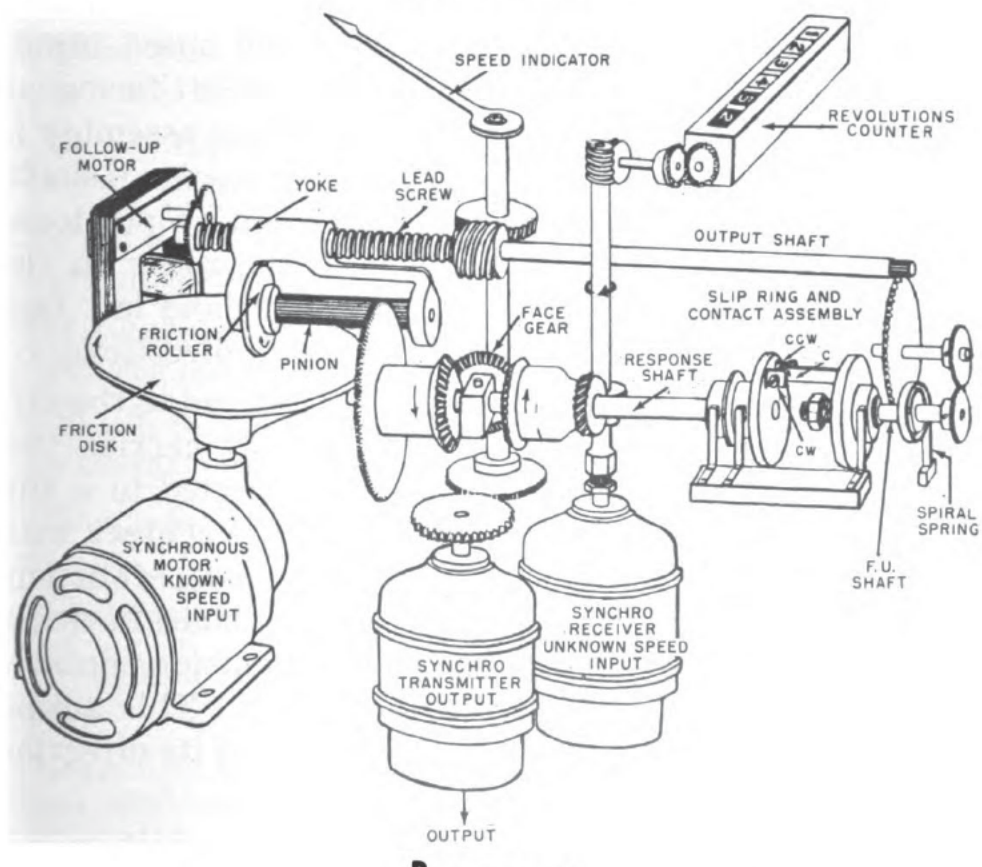
The friction disk and roller is used as the basic element in friction disk and roller assemblies to convert a variable rate of rotation to a proportional angular displacement that can be transmitted to various indicators. These assemblies are used in the underwater log system, circuit Y; propeller revolution indicator system, circuit K, and wind direction and speed system, circuit HE.

Operation

The friction disk and roller assembly is illustrated in figure 3–20. This device operates on the principle of



A SCHEMATIC



B PICTORIAL

Figure 3—20.—Friction disk and roller assembly.

comparing an unknown speed with a known speed through a differential and using the output of the differential to make these quantities approach equality. Electrical contacts operate in response to the differential output and control a followup motor that matches the two speeds (fig. 3–20, A).

The rotation that is to be converted to an angular displacement is the unknown speed input. This input is received by the synchro receiver, which is geared to the right face gear of the differential and is free to turn about the differential (response) shaft. An extension of the synchro rotor shaft drives the six-place odometer (fig. 3–20, B).

The synchronous motor is energized from the 60-cycle constant frequency bus. This motor drives the friction disk at a constant speed and is the known speed input. The friction roller drives the pinion and the left face gear of the differential through a spur gear. This assembly is also free to turn about the differential (response) shaft. Hence, the left face gear rotates at a speed proportional to the distance between the position of the roller on the disk and the center of the disk. The right and left face gears of the differential rotate in opposite directions.

The slip ring and contact assembly is secured to the differential (response) shaft. This assembly carries two outside contacts, CW and CCW, each connected to a slip ring. These contacts do not normally make contact with the center contact C, which is mounted on the followup shaft. Thus, the contact assembly can be turned in either direction so that one or the other of the outside contacts can make contact with the center contact. This action energizes the followup motor and determines its direction of rotation.

The followup motor drives the lead screw, which moves the yoke in or out (depending on the direction of rotation), thereby varying the revolutions per minute of the friction roller and the left face gear of the differential.

This action continues until the number of revolutions are the same as the right face gear of the differential. When this equality is reached, the differential (response) shaft ceases to rotate and the contact assembly opens the circuit to the followup motor.

A pinion is cut on the end of the output shaft and engages a gear train that drives the followup shaft very slowly in the same direction as the differential (response) shaft whenever the followup motor is operating. This action restores the contacts to their normal (open) position slightly before the differential (response) shaft stops rotating to prevent hunting or overtravel of the lead screw.

QUIZ

1. Name three quantities in connection with various I. C. systems that can be represented by the rotation of a shaft.
2. How is the magnitude of the quantity represented by shaft rotation increased or decreased?
3. What is the shaft value of a shaft that must be turned 10 revolutions to represent a 360° direction?
4. If a shaft has shaft value of 5° and the shaft counter indicates 20°, how many revolutions has the shaft made?
5. What is the total value of a shaft that has made 4.5 revolutions if the shaft value is 5°?
6. What is the name given to the smaller of two mating gears?
7. What kind of motion is transmitted when one gear positions another gear?
8. What kind of motion is transmitted when a gear positions a rack?
9. Gears used to transmit rotary motion between parallel shafts are called what?
10. What is the basic difference between a straight spur gear and a helical spur gear?
11. How does the meshing action of two helical gears differ from that of two spur gears?

12. Gears used to transmit rotary motion between two nonparallel shafts are called what?

13. How does a straight bevel gear differ from a spiral bevel gear?

14. What are miter gears?

15. How are the teeth arranged on an internal gear?

16. What is the relation between the axes of an external gear and an internal gear for the two gears to mesh?

17. What type of screw thread forms the groove around the body of a worm gear?

18. What is the lead of a single threaded worm if 16 turns of the worm are required to complete one revolution of the worm wheel?

19. (a) What is the lead of a double threaded worm if eight turns of the worm are required to complete one revolution of the worm wheel? (b) What is the pitch?

20. Worms are used generally where what relative magnitude of speed reduction is required?

21. What is the gear ratio between a 24-tooth driving gear and a meshing 84-tooth driven gear?

22. What are the relative directions of rotation of any two mating spur gears?

23. Where and for what purpose is an idler gear used?

24. How does an idler between two gears affect the gear ratio?

25. How is the gear ratio between a worm and worm wheel determined?

26. What is the ratio of the speed of the driving gear to the speed of the driven gear called?

27. What is the relation between gear ratio and speed ratio?

28. In figure 3–7, what is the gear ratio between the driving and the driven gears?

29. In gear trains, why is it not desirable to use a single gear reduction of as much as 12-to-1 ratio?

30. What is the function of a differential?

31. Name the three types of differentials generally used in I. C. instruments.

32. Why are 2-to-1 ratio gears required between the spider shaft (output) and the input shaft of the next (driven) mechanism in a bevel-gear differential?

33. What types of gears are used in the jewel-gear differential?

34. Jewel-gear differentials are used with (a) what relative size of mechanism, (b) what relative amount of loading and (c) what relative requirement of load accuracy?

35. Name the two types of a-c followup motors generally used in I. C. instruments.

36. What are the requirements of a servomotor with regard to (a) quick starts and stops and (b) reversibility?

37. What two types of cams are most frequently used as components of followup systems in many I. C. instruments?

38. How is the heart cam mounted on the synchro receiver rotor shaft?

39. What is the purpose of the follower spring?

40. When an incoming signal from the synchro transmitter causes the synchro receiver to turn, how is this motion transmitted to the switch contacts?

41. As the load comes into correspondence, the response shaft drives the bearing mounted synchro receiver stator in what relative direction with respect to that of the rotor?

42. In figure 3–17, what is the arithmetical relation between the signal that is used to control the output power and the input and feedback signals?

43. What is the function of the differential in figure 3–17?

44. In figure 3–18, if the input rotates continuously, what effect does this action have on the differential spider and the servomotor contacts?

45. Name the three essential elements of the single-speed synchro followup control shown in figure 3–19.

46. How is the units drum in a six-place odometer connected to the driving shaft?

47. How is the units drum in an eight-place ratchet counter connected to the driving shaft?

48. What is the function of the friction disk and roller assembly (fig. 3–21)?

CHAPTER 4

SHIP'S METERING AND INDICATING SYSTEMS

Ship's metering and indicating systems include the propeller revolution indicator system, wind direction and speed indicator system, salinity indicator system, underwater log system, profile draft indicator system, dead reckoning system, and many others.

Instruments comprising the propeller revolution indicator, wind direction and speed indicator, and underwater log systems are of watertight construction and are designed for mounting on bulkheads or panels, depending on the stations in which they are located. Windows are provided in the instrument covers where required for viewing the dials and counters. The internal units can be withdrawn individually from the housings. Dowel pins locate the units within the housings and serve as supports after the units are removed.

The incoming cables are brought through watertight terminal tubes into the instrument housings and the leads are connected to terminal strips or female connectors. The leads for the synchros, backing signals, and other components are connected to corresponding terminal strips or male connectors within the housings. Master transmitters are installed to prevent excessive overloading of the primary transmitters by the relatively large number of indicators required in the systems.

PROPELLER REVOLUTION INDICATOR SYSTEM

The propeller revolution indicator system, circuit *K*, is used to indicate instantaneously and continuously the (1) revolutions per minute, (2) direction of rotation, and (3) total revolutions of the individual propeller shafts. The information is indicated in the enginerooms, pilot house, and other required locations.

This system comprises principally (1) type-A, (2) type-B, and (3) magneto-voltmeter-type equipments. Type-A equipment is installed in large combatant ships and in many newly constructed small ships. Type-B equipment, which is installed only in small ships, is not provided with remote indicators. This type is not discussed because the principle of operation is essentially the same as that of type A, which is the more complete system. The magneto-voltmeter-type equipment is less complicated and is installed in smaller ships, such as AM's, AMS's, and many others.

Type-A Equipment

A typical type-A propeller revolution indicator system installed in a large ship is shown by the block diagram in figure 4–1. This system consists of various transmitters, transmitter-indicators, and indicators. The transmitters for shafts 1 and 4 are installed in boiler operating station 3 and those for shafts 2 and 3 are installed in the after auxiliary machinery room. These transmitters are electrically connected to transmitter-indicators in their respective throttle stations. Indicators are also installed on the gage board in the associated enginerooms and in the pilot house as required by the type of ship. Each indicator is provided with a backing signal light which, when lighted, denotes astern rotation of the propeller shaft. Certain indicators are also provided with revolution counters.

The rotary motions of the propeller shafts are transmitted by the shaft transmitters to the transmitter-indicators,

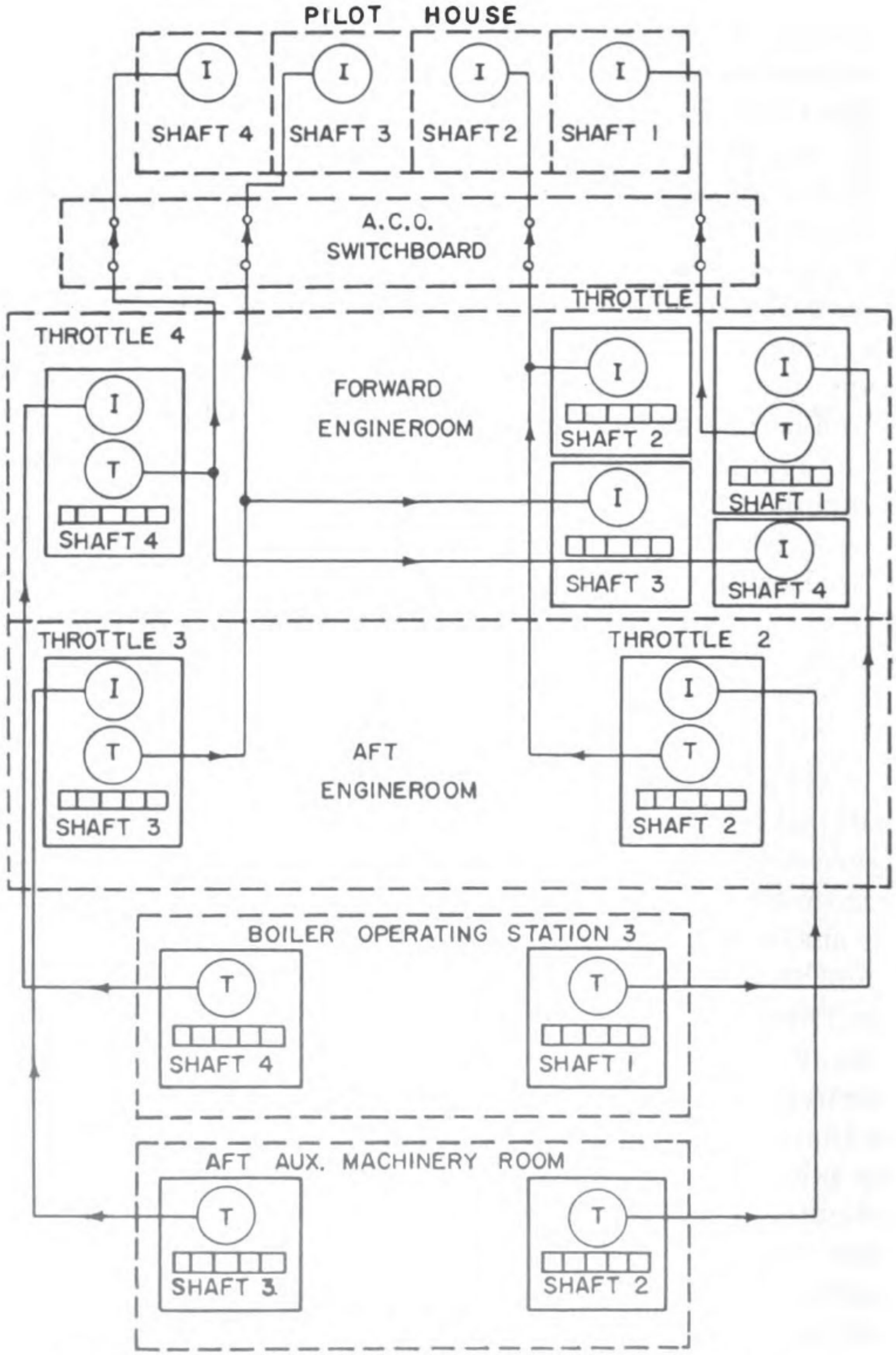


Figure 4—1.—Propeller revolution indicator system block diagram.

which convert the received rotary motions into stationary angular synchro displacements. The angular displacements, which are proportional to the speeds of the propeller shafts, are transmitted to indicators located at various stations. These indicators repeat the rpm readings received from the associated transmitter-indicators.

TRANSMITTER.—The transmitter consists of a type-5G running synchro transmitter, revolution counter, and unidirectional mechanism all mounted on an upper supporting plate, which is separated from a lower supporting plate by four posts. The entire assembly forms a complete unit that is enclosed within the housing (fig. 4–2). The transmitter is driven through internal gears located below the lower supporting plate. These gears are coupled

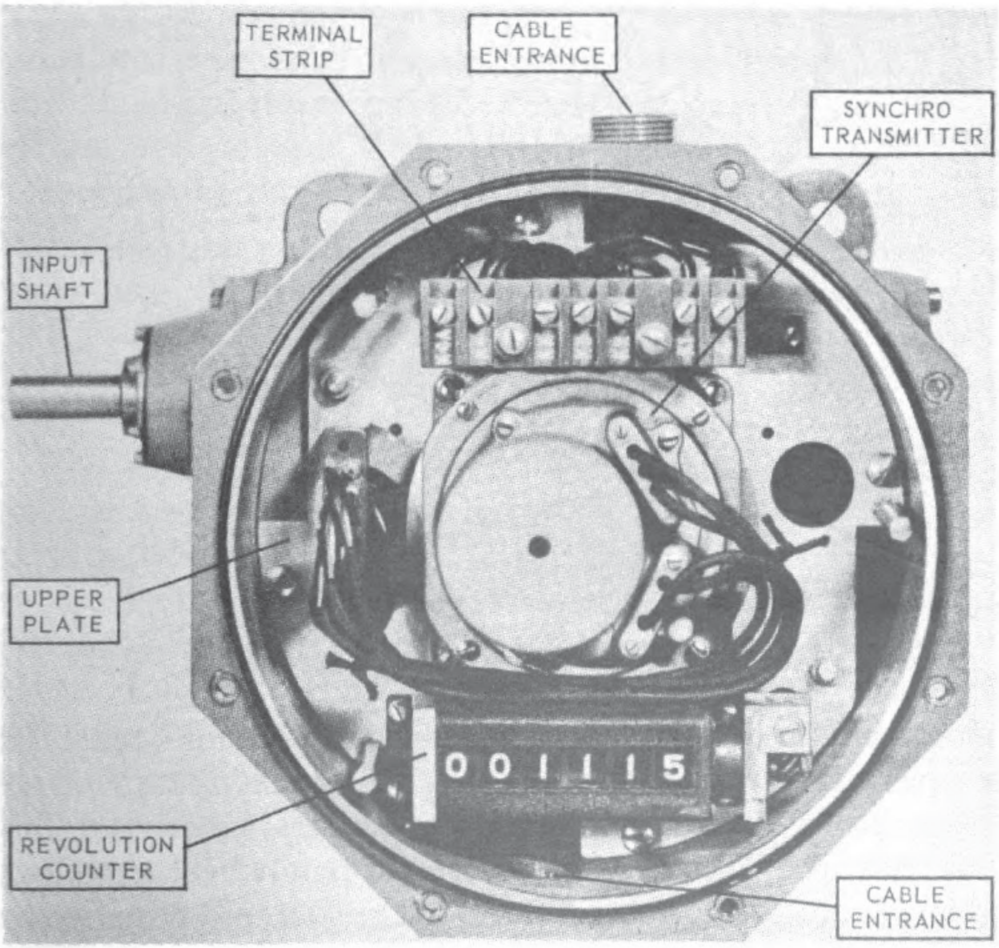


Figure 4—2.—Propeller transmitter of type-A propeller revolution indicator system.

to the end of a stub shaft of the propelling machinery and the transmitter rotates at one-half the propeller shaft speed.

The REVOLUTION COUNTER, illustrated in the schematic diagram of the shaft transmitter in figure 4–3, is driven through gearing and a flexible shaft by the type-5G synchro. The revolution counter is a standard 6-place

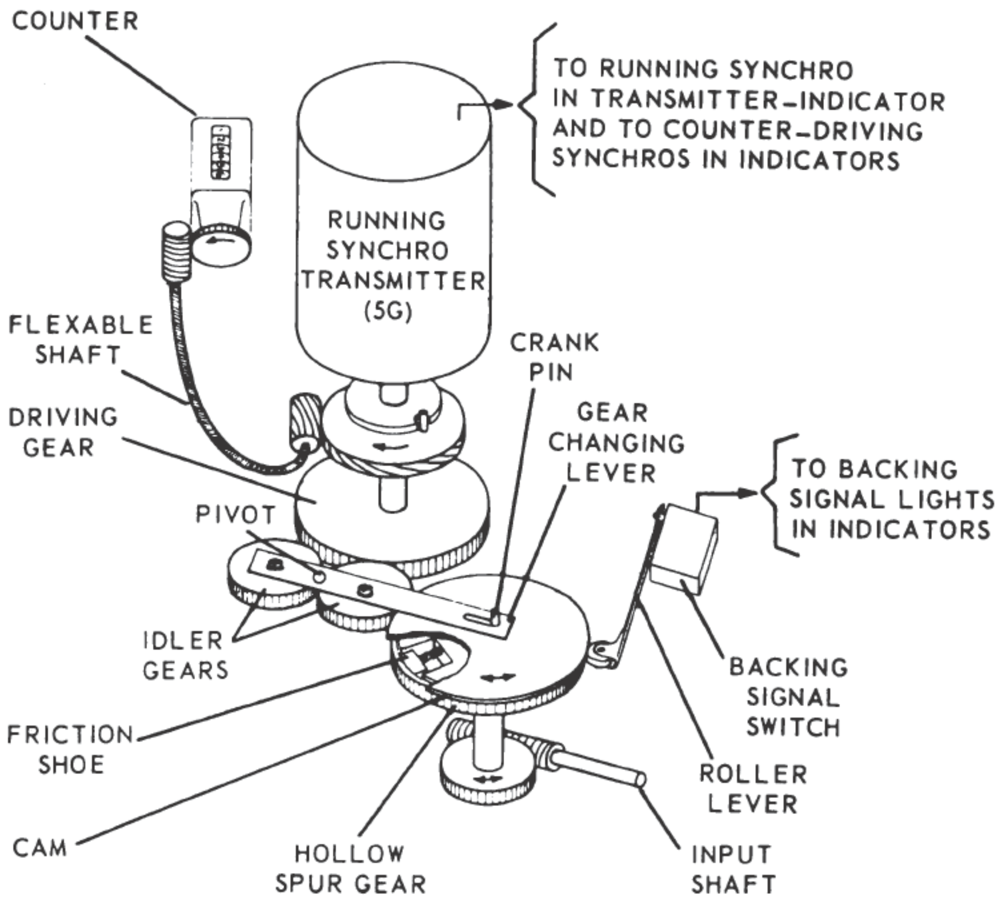


Figure 4—3.—Shaft transmitter schematic diagram.

odometer, the first wheel of which rotates at one-tenth of the propeller shaft speed. An automatic UNIDIRECTIONAL MECHANISM incorporated in the gear train between the transmitter driving gear and the worm wheel attached to the input shaft causes the transmitter and counter to turn always in the same direction with either ahead or astern rotation of the propeller shaft.

The UNIDIRECTIONAL MECHANISM (fig. 4–3) consists of a hollow spur gear, a friction-actuated cam, a change-gear lever, and two pivot-mounted idler gears.

The cam has four spring-loaded friction shoes mounted on its bottom surface, and a crank pin mounted off center on its top surface. The four friction shoes bear against the inner circumference of the hollow spur gear and turn the cam. The crank pin engages a slot in the gear-change lever so that the movement of the cam is restrained to an arc of 180°.

When the hollow spur gear reverses its direction of rotation, the crank pin on the cam moves the gear-change lever, causing the pivot-mounted idler gears to transpose their position with respect to the synchro-drive gear. This action establishes an internal drive reversal that cancels the reversal in rotation of the hollow spur gear, and thus maintains unidirectional rotation of the transmitter and counter.

A backing signal light switch is mounted on the unidirectional mechanism. The lever roller rides on the periphery of the cam and actuates the backing-signal switch when the propeller shaft rotates in a reverse direction. This action energizes the backing signals within the remotely located indicators.

The stationary contacts of the SPDT backing-signal switch are connected to terminals $K4$ and $K4$A on the terminal strip (fig. 4–8). When the transmitter is wired to the system, the $K4$ lead from the indicators must be connected to either the $K4$ or $K4$A terminal. The proper connection is determined by the rotational direction of the transmitter drive, which corresponds to astern rotation of the propeller shafts.

TRANSMITTER-INDICATOR. — The transmitter-indicator consists of a type-3F running synchro receiver, a speed-measuring mechanism, and a type-5G positioning synchro transmitter mounted on the back of a base plate (fig. 4–4). Two concentric revolving pointers indicate on the dial,

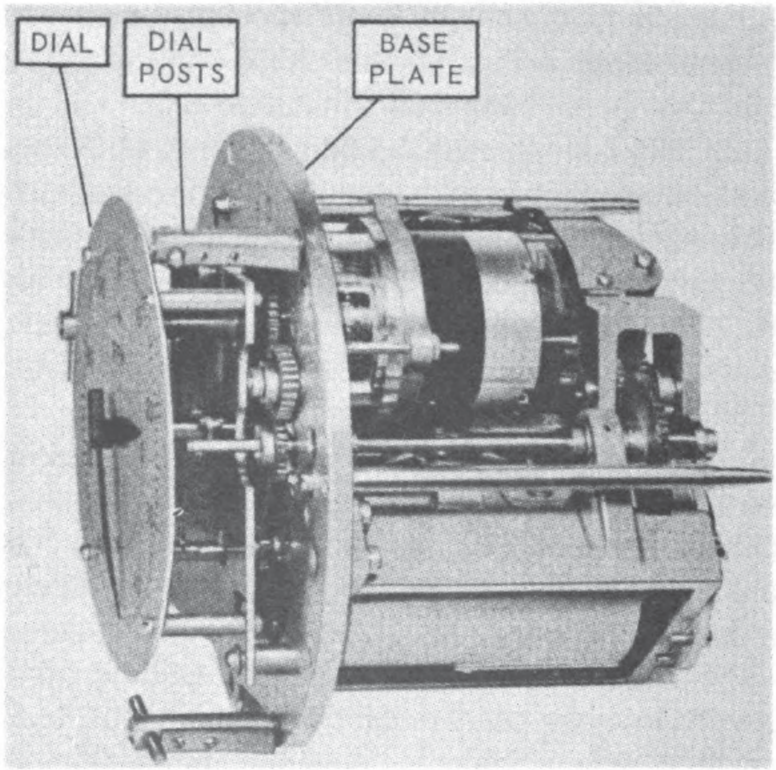


Figure 4—4.—Transmitter-indicator of type-A propeller revolution indicator system.

which has two scales, the output of the speed-measuring mechanism. The short pointer indicates in hundreds of rpm on the inner scale, and the long pointer indicates unit rpm on the outer scale. The dial and double pointers are provided only for purposes of calibration and comparison and are not visible when the cover is normally secured to the housing. The entire assembly forms a complete unit that is enclosed within the housing. This unit is not provided with a revolution counter or a backing signal.

The TYPE-3F RUNNING SYNCHRO receives and duplicates the rotary motion from the shaft transmitter and drives the input shaft of the speed-measuring mechanism, through gears, at the same speed as the propeller shaft. The TYPE-5G POSITIONING SYNCHRO receives the angular displacement from the speed-measuring mechanism and transmits this displacement to the remotely located indicators.

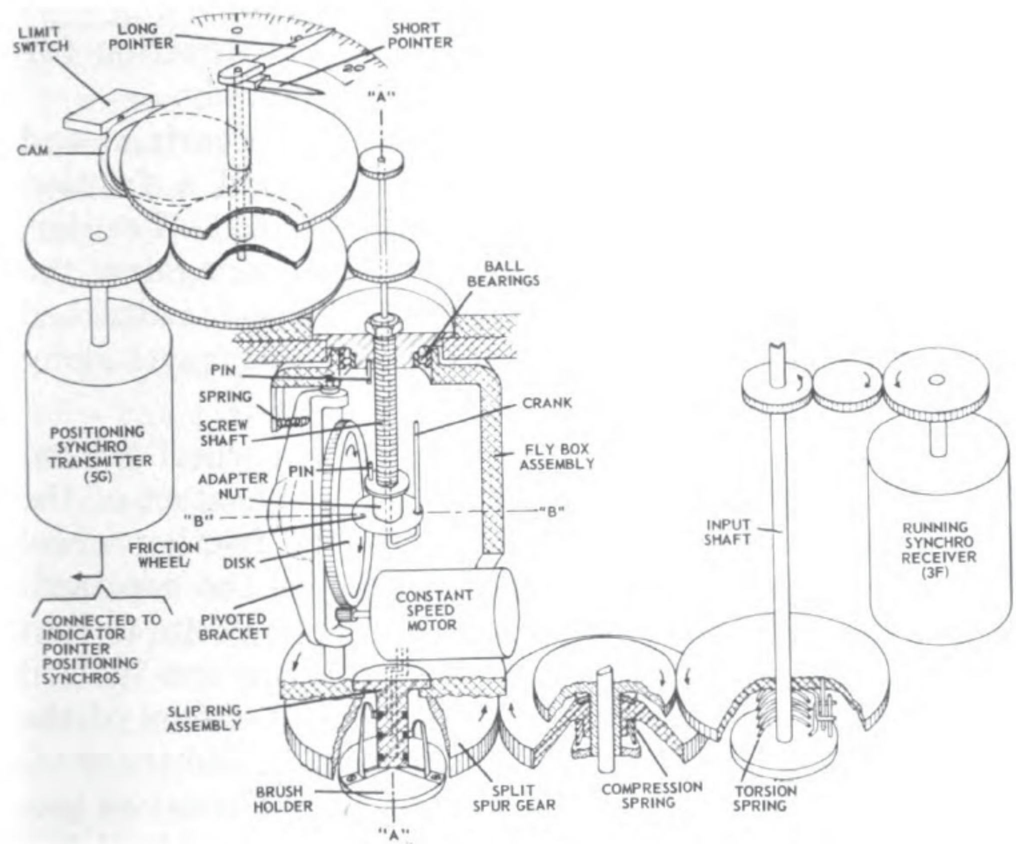


Figure 4—5.—Transmitter-indicator schematic diagram.

The SPEED-MEASURING MECHANISM, illustrated in the schematic diagram of the transmitter-indicator in figure 4–5, is similar in operation to the friction disk and roller assembly described in the chapter on basic mechanisms. It is an automatic comparison device that is continuously self-adjusting to balance the unknown propeller shaft speed against a known fixed speed. When the propeller shaft speed is 200 rpm, the input shaft drives the flybox assembly through gears at a speed of 300 rpm, which corresponds to full-scale pointer indication.

The torsion coupling spring, friction washer, and associated compression spring in the gear train, which drive the flybox assembly, enable the type-3F running synchro to start under all conditions, including interruption and restoration of the power supply when the shaft transmitter is turning. These components also act as a damper to

prevent oscillating of the running synchro, enabling it to build up a positive torque in the forward direction for starting the inertia load of the flybox assembly.

The flybox assembly is mounted on ball bearings and carries a disk on a pivoted bracket, around a friction wheel. The axis of the pivoted bracket is 3/8″ off center, so that a compression spring presses the disk against the edge of the friction wheel. The friction wheel is attached to an adapter nut that is threaded to permit travel along the stationary screw shaft.

Rotation of the flybox turns the friction wheel around the screw shaft by means of the frictional contact of the disk with the friction wheel. Hence, the friction wheel advances along the screw shaft. Because the constant-speed motor drives the disk in a direction opposite to that of the flybox, the friction wheel tends to return inward toward the center of the disk. Thus, the rotation of the flybox tends to carry the friction wheel OUT, and the rotation of the disk tends to drive it back IN. These two motions neutralize each other when the friction wheel has been screwed outward far enough from the center of the disk. The friction wheel now comes to rest along the screw shaft in a condition of balance.

Hence, the two simultaneous peripheral speeds of the disk around the AA and BB axes respectively are equal at the circle of contact with the friction wheel. The disk radius of the circle of contact for any given condition of balance is proportional to the speed of the propeller shaft. At full propeller shaft speed, the edge of the friction wheel is at a radius of exactly 1 inch from the center of the disk; at one-half speed it is 1/2 inch; and so on. Therefore, the friction wheel is positioned along the screw shaft a distance exactly proportional to the propeller shaft speed. The screw shaft and adapter nut are designed so that, from zero to full-speed indication, the friction wheel advances exactly 10 turns along the screw shaft.

The friction wheel is coupled to the pointer gears by

means of a crank so that the short pointer indicates in hundreds of rpm on the inner scale and the long pointer indicates in unit rpm on the outer scale. The displacement of the long-pointer shaft is transmitted through gears to the positioning synchro transmitter, which transmits the angular position to indicators at the remote stations. A 360° rotation of the synchro rotor corresponds to full-scale deflection of the indicator pointers.

Power for the constant-speed motor is supplied through slip rings and brushes because this motor revolves with the flybox. A cam-operated switch automatically disconnects power from the motor when the propeller shaft stops or its speed decreases to nearly zero on the dial. Mechanical stop pins are provided to prevent the friction wheel from running off the edge of the disk on overspeed. These stop pins also limit the maximum scale reading to approximately 225 rpm.

The electrical circuit of the master transmitter-indicator is shown in figure 4–8.

INDICATOR WITH REVOLUTION COUNTER.—The indicator with revolution counter installed in throttle station 1 is used to indicate the rpm and total revolutions of the associated propeller shaft (fig. 4–6). This instrument consists of a type-3F positioning synchro receiver and a type-1F running synchro receiver mounted on the back of a base plate. Two concentric revolving pointers indicate on the dial, which has two scales, the rpm of the associated propeller shaft. The type-3F synchro, driven by the type-5G positioning synchro in the associated transmitter-indicator unit, positions the double indicator pointers through gears.

The revolution counter register is located at the bottom of the indicator dial. The type-1F running synchro, driven by the associated shaft transmitter, drives the revolution counter through gears. The entire assembly forms a complete unit that is enclosed within the housing. A backing signal light in this unit is energized by the uni-

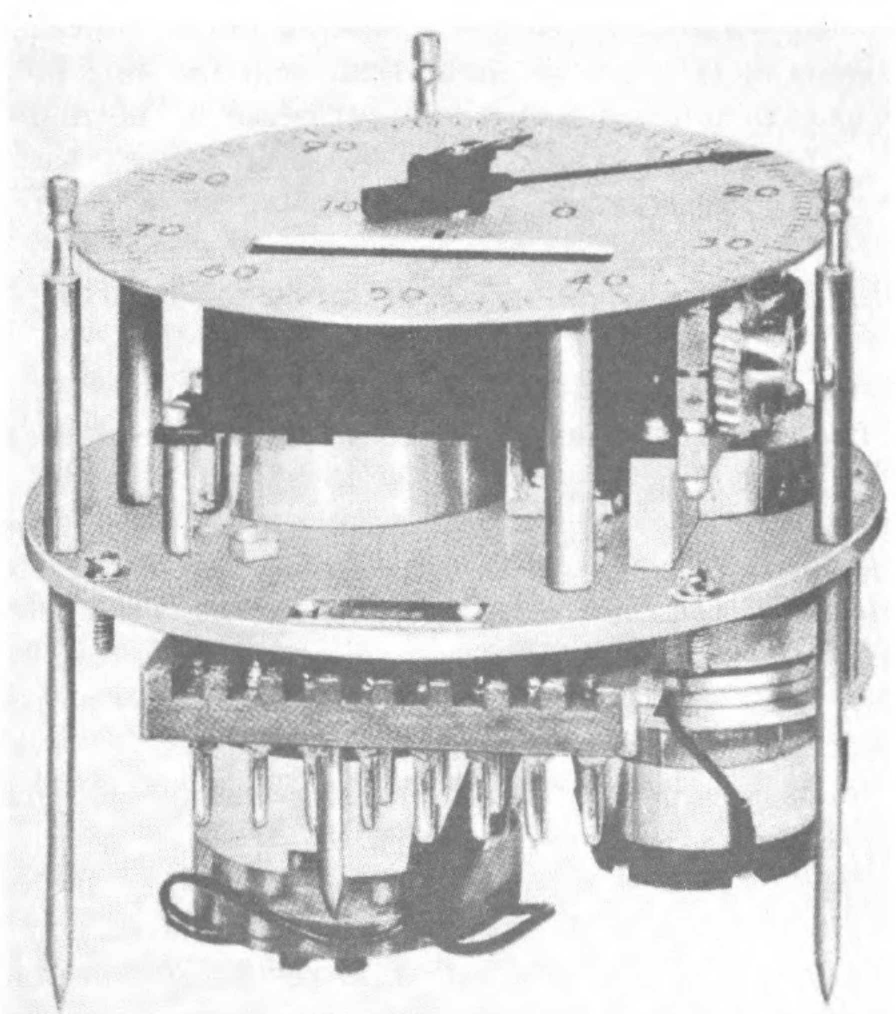


Figure 4—6.—Indicator with revolution counter of type-A propeller revolution indicator system.

directional mechanism in the shaft transmitter when the propeller shaft rotates in the astern direction.

The electrical circuit of the indicator with revolution counter is shown in figure 4–8.

INDICATOR.—The indicator installed in the pilot house is used to indicate the rpm of the associated propeller shaft (fig. 4–7). This instrument consists of a type-3F positioning synchro receiver mounted on the back of a base plate. Two concentric revolving pointers indicate on the dial, which has two scales, the rpm's of the associated propeller shaft. The type-3F synchro, driven by the type-5G positioning synchro in the associated master transmit-

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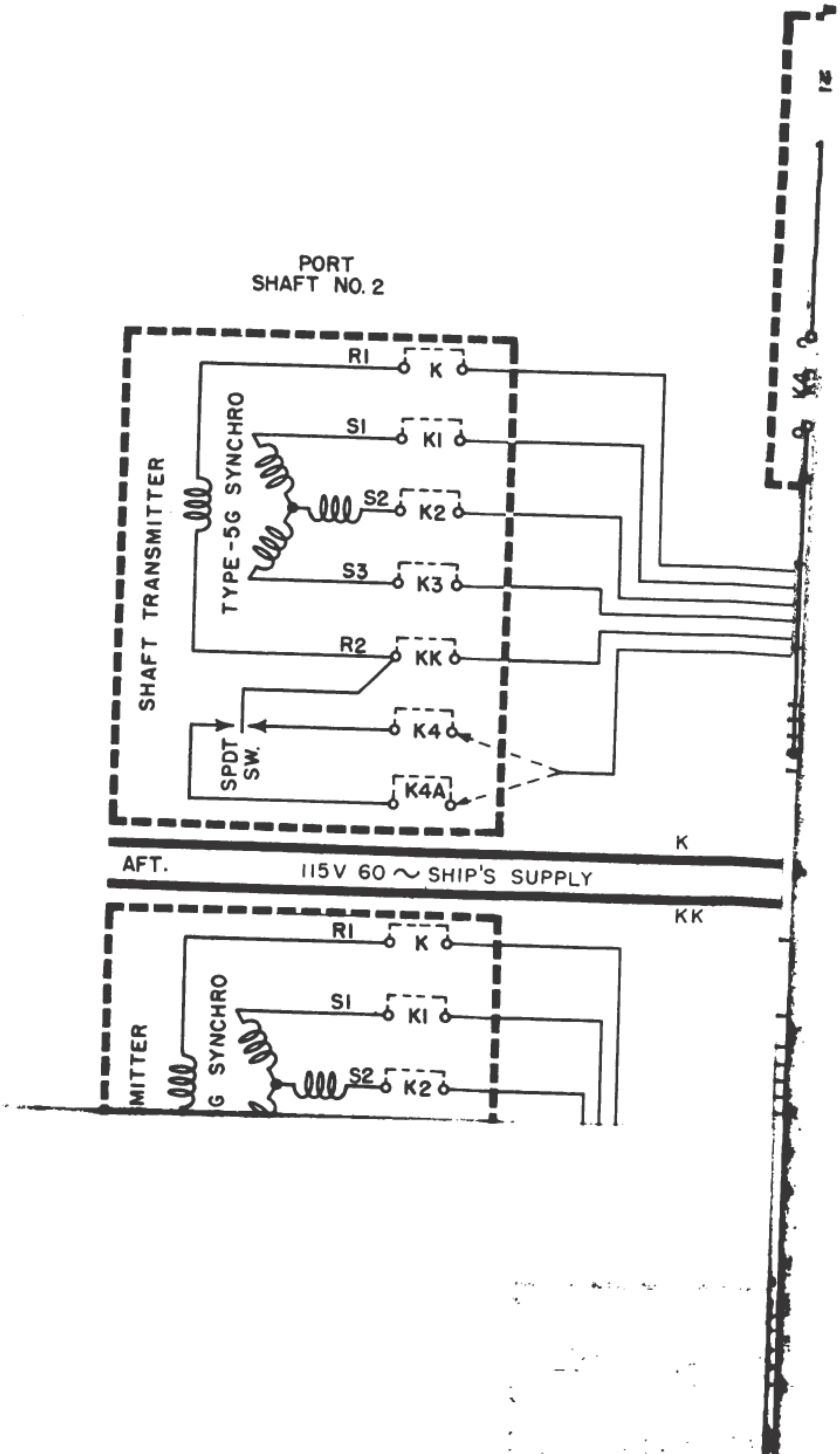

PORT
SHAFT NO. 2
SHAFT TRANSMITTER
TYPE-5G SYNCHRO
R1
K
S1
K1
S2
K2
S3
K3
R2
KK
K4
SPDT SW.
K4A
AFT.
115V 60 ~ SHIP'S SUPPLY
K
KK
MITTER
G SYNCHRO
R1
K
S1
K1
S2
K2

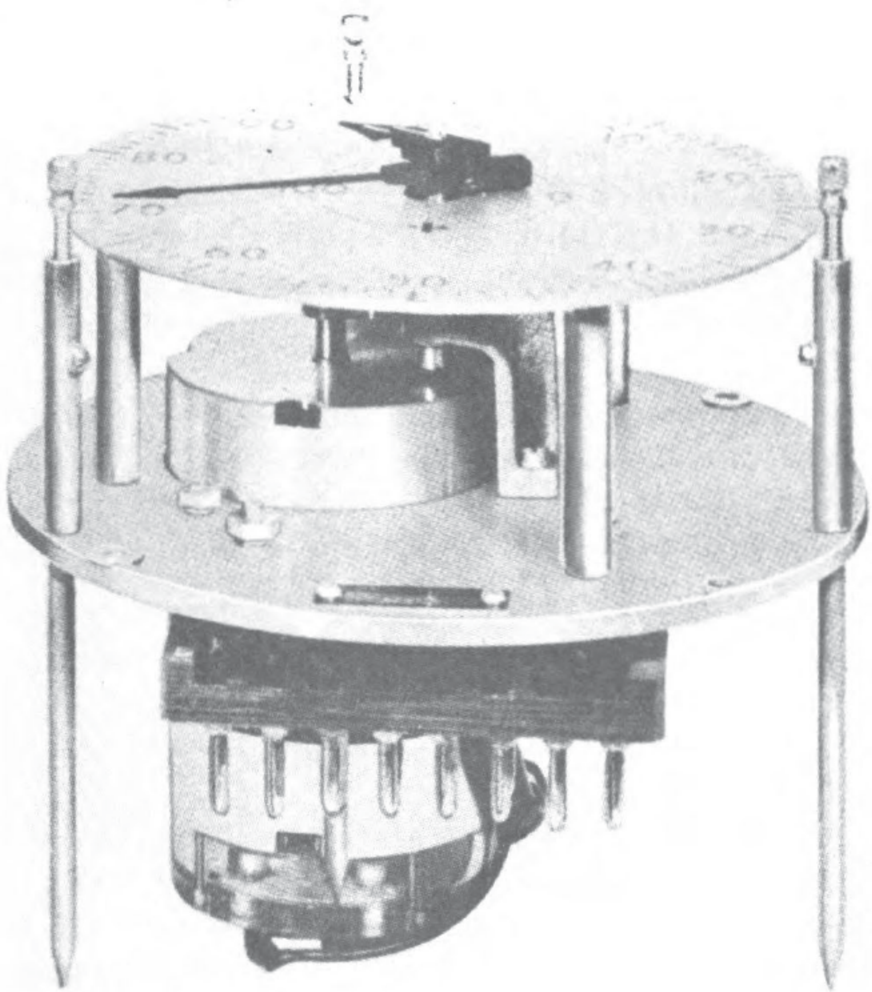


Figure 4—7.—Indicator of type-A propeller revolution indicator system.

ter-indicator (fig. 4–5), positions the double indicator pointers through gears. The entire assembly forms a complete unit that is enclosed within the housing. This indicator is provided with a backing signal that is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the reverse direction.

The electrical circuit of the indicator is shown in figure 4–8.

A typical propeller revolution indicator system installed in ships having two propeller shafts is shown by the schematic diagram in figure 4–8. The entire system is designed

for single-phase, 115-volt, 60-cycle service. Separate terminals CF and CFF are provided for the constant-speed motor in the transmitter-indicator unit. If the ship is equipped with a special accurately controlled frequency supply, the jumpers should be removed from terminals CF and CFF and the controlled-frequency supply connected directly to these terminals. This procedure is recommended because slight deviations from 60 cycles will cause corresponding errors in the rpm readings of all the indicators. The frequency of the current required for the system, with the exception of the constant-speed motor, can vary as much as ± 10 percent without affecting the performance or accuracy of the system.

Magneto-Voltmeter Type of Equipment

The magneto-voltmeter type of equipment consists of a transmitter of the magneto type geared to the propeller shaft with indicators of the voltmeter type connected directly to the magneto.

A typical magneto-voltmeter type of propeller revolution indicator system is shown in figure 4–9. The speed of the propeller shaft is converted by the magneto into a proportional d-c voltage. The indicators receive this voltage and indicate on the associated scales the rpm of the propeller shaft. The magneto-voltmeter type of indicating equipment is self-energizing and does not require a separate power source for its operation.

TRANSMITTER.—The transmitter, coupled to the propeller shaft, is used to generate and transmit the functions of speed, direction, and total number of revolutions of the propeller shaft. This instrument consists of a magneto, a type-1G synchro transmitter, a revolution counter, and a unidirectional mechanism all mounted on the front of a base plate (fig. 4–10). The entire assembly forms a complete unit that is enclosed within the housing.

The MAGNETO is a permanent-magnet type of d-c generator that is driven through two bevel gears at a speed proportional to that of the propeller shaft. The output

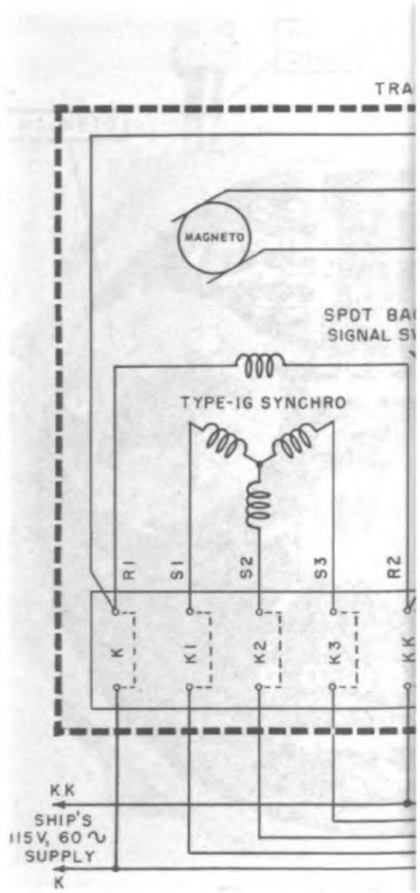

TRA
MAGNETO
SPDT BA
SIGNAL S
TYPE-IG SYNCHRO
R1
S1
S2
S3
R2
K
K1
K2
K3
KK
K.K
SHIP'S
115V, 60 ∿
SUPPLY
K

Figure 4

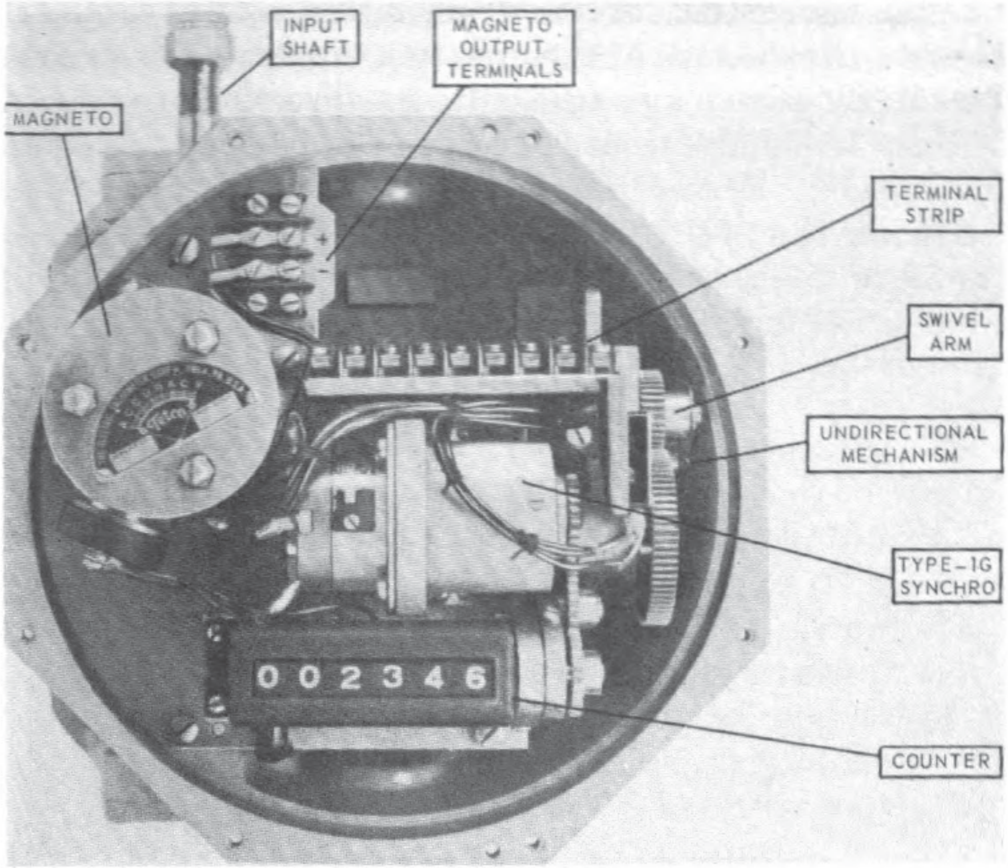


Figure 4—10.—Magneto type of transmitter.

of the magneto is 2.92 volts for every 1,000 rpm of the armature. The permanent-magnet field is stationary and the armature rotates. The armature winding consists of a distributed, closed-circuit type of winding, which is connected to a multi-segment commutator. The segments and brushes are made of gold in order to prevent corrosion and to maintain satisfactory conductivity. The polarity of the generated voltage changes with reversal of armature rotation. For this reason, the output of the magneto is fed through the reversing contacts of a DPDT relay to the terminals marked "+" and "—". Whenever the propeller shaft rotates in the reverse direction, the relay coil is energized by an SPDT switch which is automatically actuated by a swivel arm in the unidirectional mechanism. This action causes the relay contacts to transpose the magneto connections to the terminal strip

so that the output of the transmitter retains uniform polarity irrespective of the direction in which it is driven. This SPDT switch also transmits the direction of rotation because it simultaneously energizes a backing signal in the remotely located indicators.

The REVOLUTION COUNTER and TYPE-1G SYNCHRO illustrated in the schematic diagram of the magnet type of transmitter in figure 4–11, are mechanically driven at one-

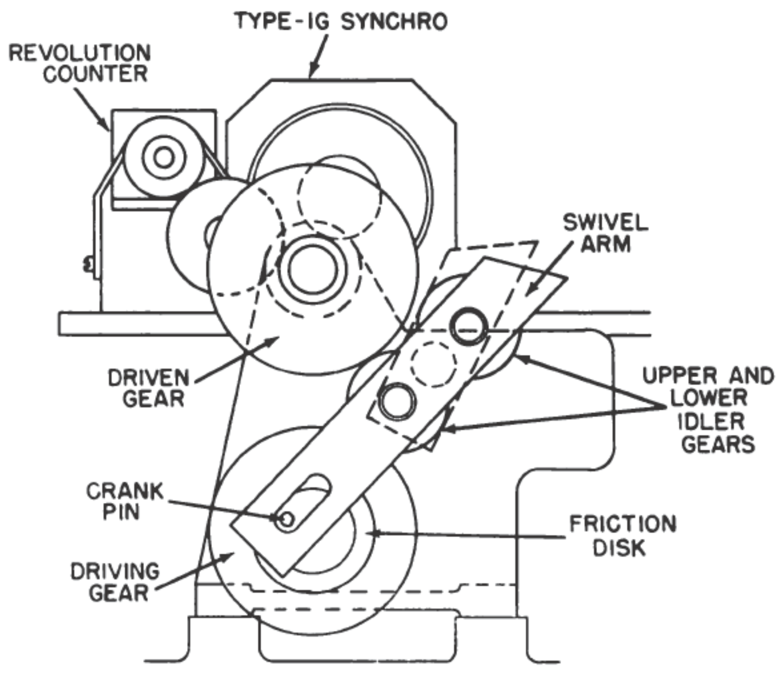


Figure 4—11.—Magneto type of transmitter schematic diagram.

tenth the propeller shaft speed through appropriate gearing by the input shaft. The revolution counter indicates the total number of revolutions at the transmitter and the type-1G synchro transmits these revolutions to the type-1F synchro that drives the associated revolution counter in the remotely located indicators.

In order to add the rpm in both the ahead and astern directions of propeller shaft rotation, a UNIDIRECTIONAL MECHANISM (fig. 4–11) is incorporated in the gear train that drives the type-1G synchro and the revolution

counter. This mechanism consists of a friction disk, two swivel-mounted idler gears, and a spring lever. The two swivel-mounted idler gears are located between the driving and driven gears so that the driven gear is alternately driven by either the upper or lower idler gear, as determined by the position of the swivel arm.

The spring lever is attached to the swivel arm, the lower end of which is slotted and engages a crank pin located off-center on the friction disk. The friction disk presses against the driving gear and rotates with it until the crank pin reaches the lower extremity of the slot in the lever where it is restrained. When the driving gear reverses direction of rotation, the disk rotates with it until the crank pin reaches the upper extremity of the slot in the lever where it is again restrained. Hence, the rotary motion of the friction disk simultaneously rocks the swivel arm causing a transposition of the upper and lower idler gears with respect to the driven gear. This action automatically drives the driven gear counterclockwise irrespective of the direction of rotation of the driving gear.

INDICATOR WITH REVOLUTION COUNTER.—The indicator with revolution counter consists of a meter, a type-1F synchro repeater, a revolution counter, and a backing signal indicator. The indicator installed in the throttle station (fig. 4–12) is used to indicate the rpm and the total revolutions of the propeller shaft and astern propeller shaft rotation. A pointer located in the center of the dial indicates the rpm of the propeller shaft. The revolution counter register is located at the bottom of the indicator dial. The entire assembly forms a complete unit that is enclosed within the housing. The backing signal indicator in this unit is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the astern direction.

The METER is energized by the generated output voltage of the d-c magneto installed in the shaft transmitter. It

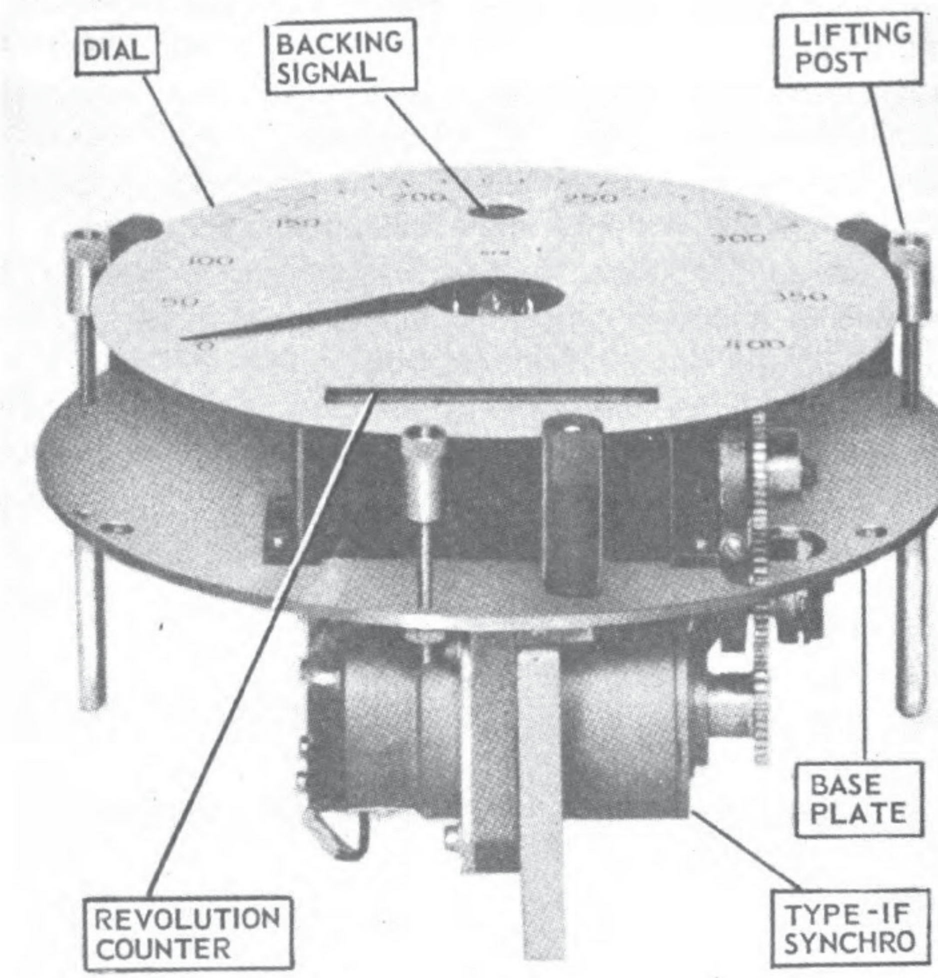


Figure 4—12.—Indicator with revolution counter of magneto voltmeter type of propeller revolution indicator system.

is essentially a d-c voltmeter calibrated in terms of shaft rpm so that an impressed terminal voltage of 3.5 volts will cause the pointer to deflect full scale.

The REVOLUTION COUNTER is driven through gears by the TYPE-1F SYNCHRO to give the total rpm of the propeller shaft.

The BACKING SIGNAL INDICATOR (composed of two lamps in parallel) is energized from the secondary of a 115/6-volt transformer. The lamps are automatically energized by an SPDT switch that is actuated by the motion of the swivel arm in the unidirectional mechanism.

A red target window located at the top of the dial is illuminated when these lamps are energized.

INDICATOR.—The indicator that is installed in the pilot house is used to indicate the rpm of the propeller shaft. This instrument is similar in appearance and construction to the indicator previously described (fig. 4–12) except that it is not provided with a revolution counter.

WIND DIRECTION AND SPEED INDICATOR SYSTEM

The wind direction and speed system, circuits *HD* and *HE*, is used to indicate instantaneously and continuously the (1) wind direction in degrees relative to the ship's heading and (2) wind speed in knots relative to the ship. A gyrocompass repeater is provided as an accessory to the system in order to determine the TRUE wind direction.

This system comprises type-A and type-B equipments. Type-A equipment utilizes a wind speed detector provided with anemometer cups for converting the wind velocity into rotary motion whereas type-B equipment utilizes a wind speed detector provided with a propeller for this conversion. Only type-B equipment is discussed but the principle of operation of both types is essentially the same.

Type-B Equipment

The type-B wind system is designed to be much lighter in weight than the type-A system. In the type B1 and B3 equipment, transmission between units of the system is accomplished by small synchro units. The type-B2 system uses small synchro units in the wind-direction circuit but the wind-speed circuit consists of a magneto coupled to the propeller, with voltmeters graduated in knots for the speed indications, thus eliminating the master wind-speed transmitter.

A type-B3 wind direction and speed indicator system consists of various transmitters and repeater indicators installed in various navigational spaces throughout the

ship. Two combined wind direction and wind speed transmitters are installed on the foremast, one on the port side and the other on the starboard side. A master wind direction and speed transmitter is installed in the I.C. room. Combined wind direction and speed repeater-indicators are installed in various locations as required by the type of ship.

The combined wind direction and speed transmitter mounted on the foremast is a dual-purpose instrument for transmitting wind direction and wind speed.

It transmits WIND DIRECTION by means of a synchro that is positioned by the wind vane. The angular positions of this synchro are transmitted to a synchro in the wind direction unit of the master wind direction and speed transmitter in the I.C. room. A synchro in this unit transmits damped angular positions to the remotely located wind direction indicators.

It transmits WIND SPEED by means of a synchro that is rotated by the wind propeller. The rotary motions of this synchro are received by a synchro in the wind speed unit of the wind direction and speed transmitter in the I.C. room. The rotary motion is converted to proportional angular displacement by a roller and disc assembly. This assembly positions a transmitting synchro which transmits the angular displacements to the various speed indicators. Each individual indicator circuit is controlled by means of multiple outputs provided from the master transmitter through the I.C. switchboard.

FOREMAST DETECTOR.—The foremast-mounted wind direction and speed detector is shown in figure 4–13. The rotor assembly is held directly into the wind by the vane assembly and rotates at a speed that is proportional to the intensity of the wind striking the blades. The rotor turns at 2,380 rpm with a wind intensity of 100 knots. The enclosing case and wind vane are made of thin-gage monel metal integrally formed into a streamline shape with a relatively large tail surface (fig. 4–13, A).

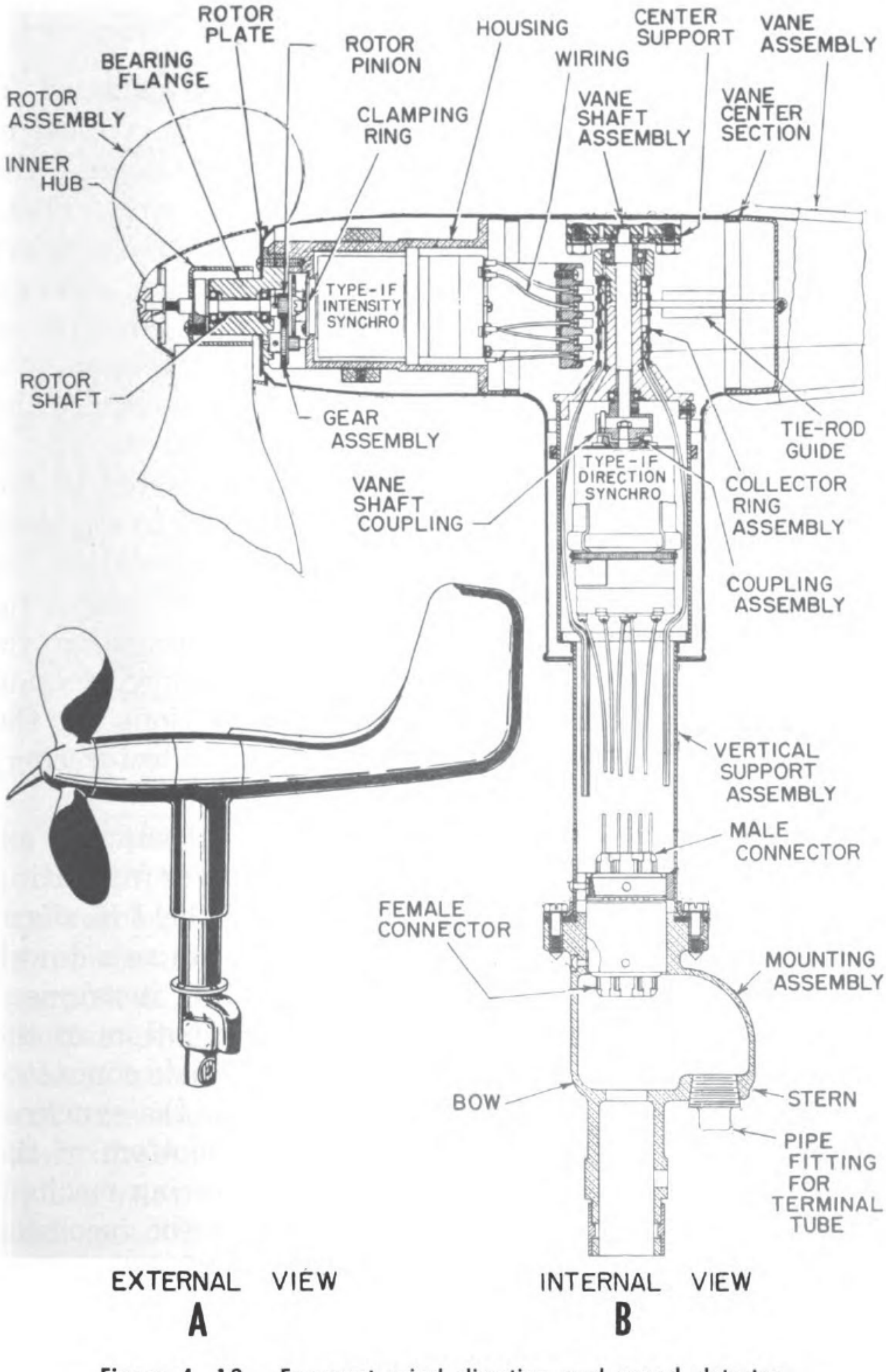


Figure 4—13.—Foremast wind direction and speed detector.

This instrument consists of a type-1F direction synchro transmitter and a type-1F speed synchro transmitter combined within a single case.

The DIRECTION SYNCHRO (fig. 4–13, B) is mounted in the vertical support assembly and is directly coupled to the vane so that when the wind positions the vane, the synchro is displaced the same angular amounts. These angular positions are transmitted electrically to a synchro repeater in the wind direction unit of the master wind direction and intensity transmitter. Because wind directions are indicated in relative bearings, the direction synchro is set to electrical zero when the vane points to the bow of the ship.

The SPEED SYNCHRO (fig. 4–13, B) is mounted in the head of the vane and is coupled through gears to a propeller type of rotor. The synchro rotates 1 revolution for each 12.5 revolutions of the propeller. These reduced rotary motions are transmitted electrically to a synchro repeater in the wind speed unit of the master wind direction and speed transmitter. Electrical connections to the speed synchro are provided by means of collector rings and brushes.

The mounting assembly and the vertical support assembly (fig. 4–13, B) are provided with flanges for bolting the two sections together. The detector is held in alignment by means of a mounting bolt that serves as a dowel. The incoming cable is brought into the instrument through a watertight terminal tube in the bottom of the mounting assembly and is connected to a female connector in the top of this assembly. The leads for the synchros are connected to a male connector in the bottom of the vertical support assembly. Thus, the detecting mechanism can be removed without disconnecting the incoming leads or disturbing the alignment (Fig. 4–18).

MASTER TRANSMITTER.—The master wind direction and speed transmitter (fig. 4–14) located in the I. C. room consists of a (1) wind direction unit and (2) wind speed

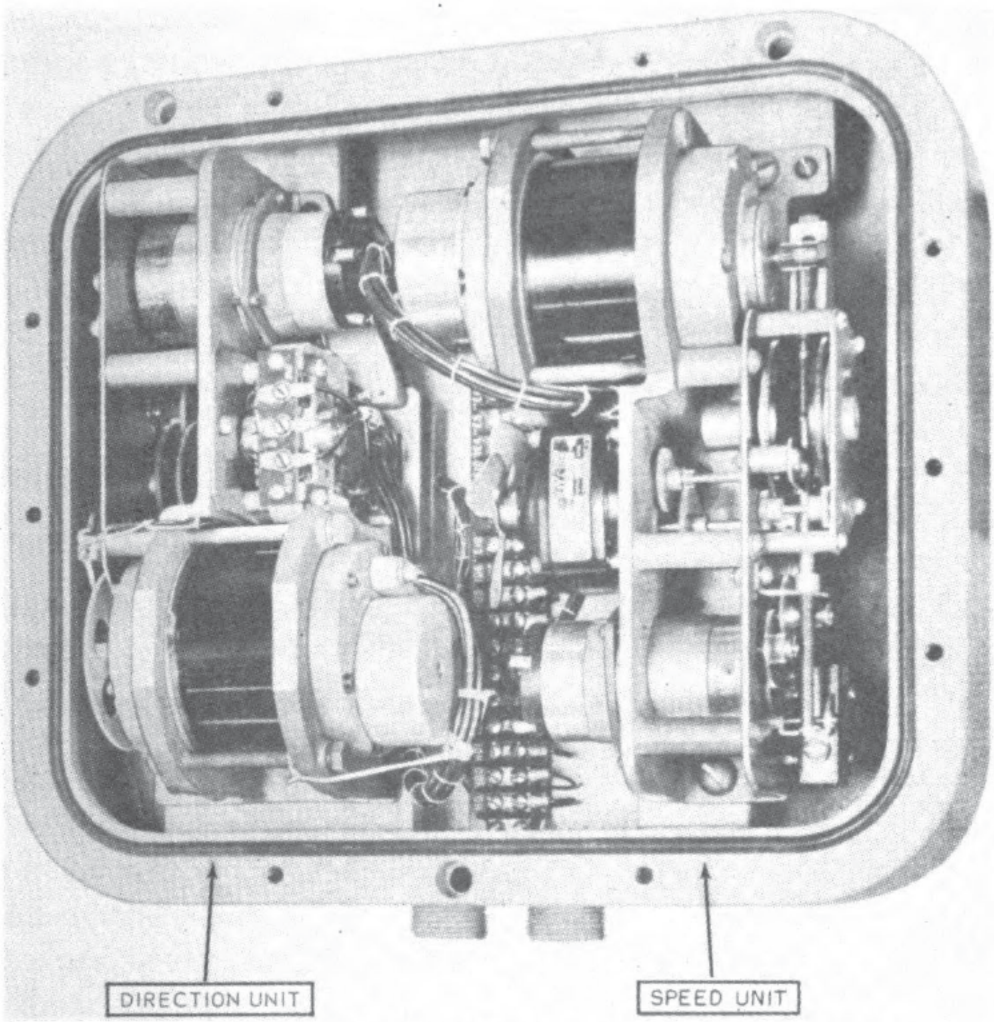
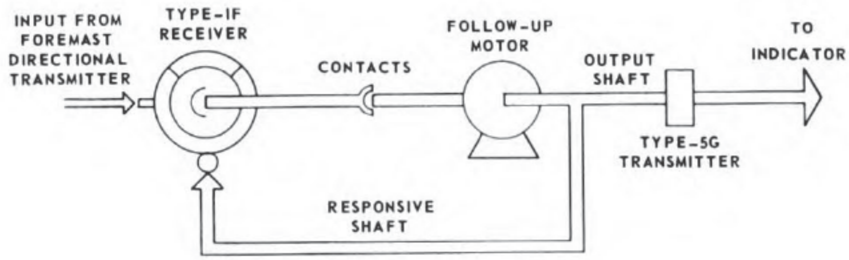


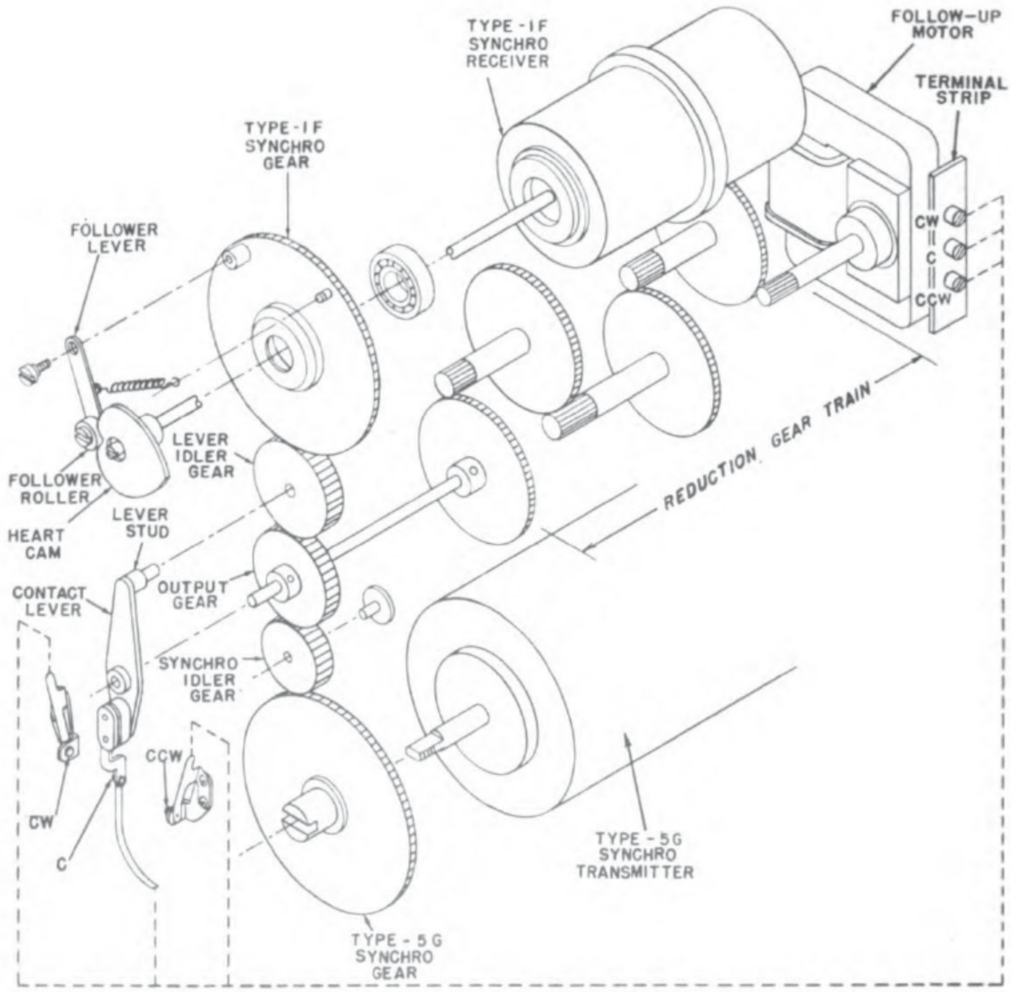
Figure 4—14.—Master wind direction and speed transmitter.

unit each mounted on individual base plates to form two complete units that are enclosed within the housing. The purpose of the wind direction and speed transmitter is to receive the angular directional displacements and the rotary motions from the respective foremast detectors, and to retransmit these indications and displacements to wind direction and speed indicators (Fig. 4–18).

The WIND DIRECTION UNIT of the master wind direction and speed transmitter (fig. 4–15) is essentially a servo unit comprising a type-1F synchro receiver, a synchro followup control, and a type-5G synchro transmitter. The arrangement of these components is shown by the schematic diagram in figure 4–15, A. The type-1F synchro



A SCHEMATIC



B EXPLODED VIEW

Figure 4—15.—Wind direction unit of master wind direction and speed transmitter.

receives the angular displacements of the foremast directional synchro; the synchro followup control provides a means of damping these displacements through gears; and the type-5G synchro retransmits these damped indications at a predetermined rate to the remotely located wind direction indicator.

The followup control includes a heart cam, an SPDT switch, a followup motor, and gears. The arrangement of these components is shown in the exploded view in figure 4–15, B.

Turning the type-1F receiver rotor causes the follower lever to rotate the type-1F synchro gear, through the follower lever action in the indent of the heart cam. Turning the type-1F synchro gear causes the lever idler gear to move a short distance along the periphery of the type-1F synchro gear and the output gear. This movement is transmitted to the contact lever which in turn limits the amount of lever-idler-gear displacement by the mechanical closure of the switch contacts. The center contact, C, of the SPDT switch is located on the opposite end of the contact lever. The rotating movement of the contact lever brings center contact C to bear against either stationary contact CW or CCW, depending upon the direction of rotation of the type-1F synchro rotor, to control the direction of rotation of the shaded-pole followup motor.

The followup motor rotates the output gear through a reduction gear train and positions the type-5G synchro gear, which is attached to the synchro rotor, through an idler gear. The type-1F synchro gear is restrained by the action of the follower roller in the valley of the heart cam and does not move. Thus the contact lever idler gear travels on the periphery of the type-IF synchro gear in the opposite direction until the switch opens and the followup motor stops.

A movement of the type-1F synchro receiver rotor in the opposite direction closes the other stationary switch

contact to cause the followup motor to reposition the type-5G synchro transmitter and the type-1F synchro gear in the opposite direction (fig. 4–18).

The WIND SPEED UNIT of the master wind direction and speed transmitter (fig. 4–16) comprises a roller-disk mechanism, a type-1F synchro receiver, a roller gear assembly with worm and circular rack, and a type-5G synchro transmitter. The type-1F synchro receives the rotary motions from the foremast detector; the roller

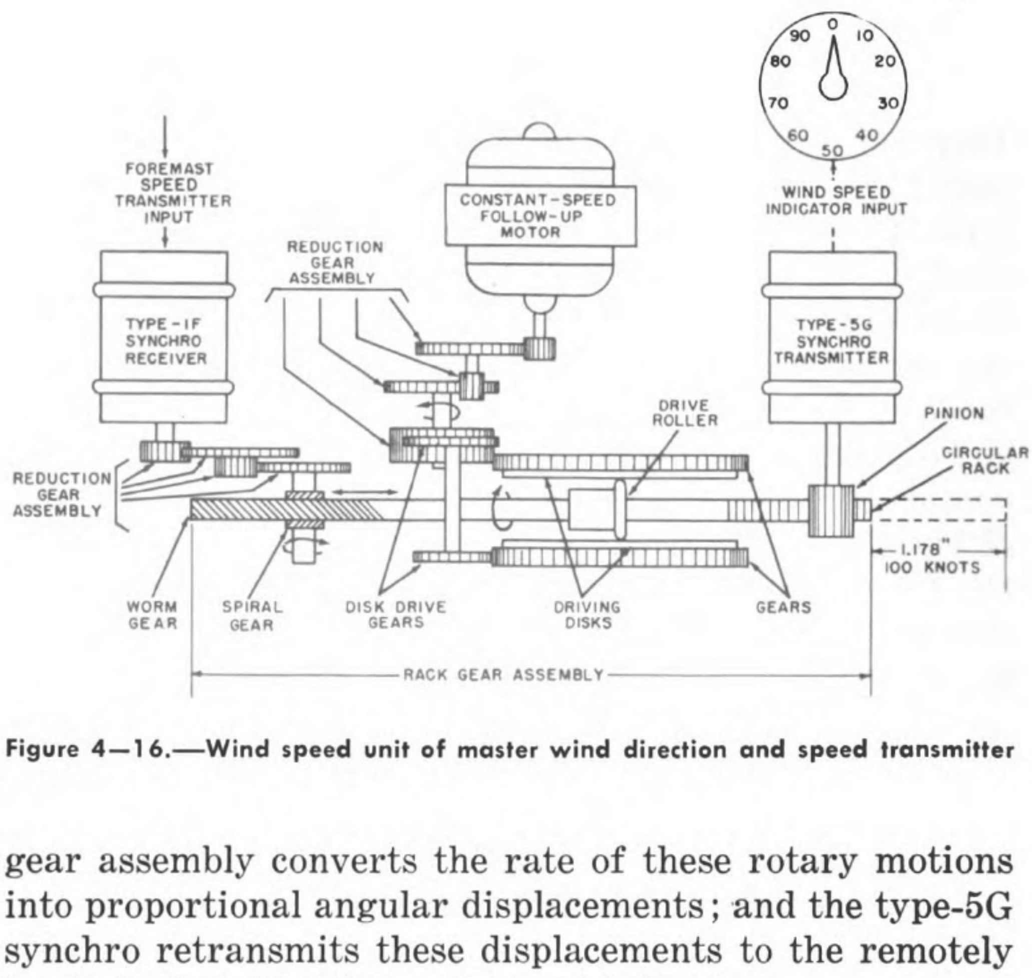


Figure 4—16.—Wind speed unit of master wind direction and speed transmitter

gear assembly converts the rate of these rotary motions into proportional angular displacements; and the type-5G synchro retransmits these displacements to the remotely located wind direction and speed indicators.

The type-1F synchro, which rotates at the same speed as the type-1F speed synchro in the foremast detector, transmits its rotary motion through reduction gears to the worm of the roller gear assembly. This gear reduc-

tion terminates with a spiral gear that engages the worm of the roller gear. The action of the spiral gear against the worm of the roller gear assembly is that of a pinion on a rack which drives the drive roller away from the center of the two driving disks in a linear motion. However, the roller with its integral worm and circular rack is rotated by the two driving disks, which are turned in opposite directions, by a constant-speed motor through a reduction gear assembly and the two disk drive gears.

The speed of the circular motion of the roller depends upon the position of the drive roller with respect to the center of the driving disks. The speed of the roller increases as the roller approaches the edge of the disk. Hence, the drive roller receives circular motion and linear motion simultaneously. Although the driving action of the spiral gear against the worm tends to drive the roller away from the center of the two disks, the resultant motion from the revolving of the worm engaging the spiral gear is toward the center of the disks. When the circular motion and the linear motion balance each other, the roller assumes a position of displacement from the center of the disks that is proportional to the rotor speed of the wind direction and speed transmitter.

The drive roller is attached to the roller gear assembly shaft and positions this shaft laterally. The rack of the roller gear assembly engages a pinion of the shaft of the type-5G synchro transmitter, thus transforming linear motion into angular motion. The angular motion is transmitted to the remotely located wind speed indicators (fig. 4–18). The type-5G synchro transmitter is set to electrical zero when the wind speed is zero.

A low-limit cutout switch (not shown) is provided to open the circuit to the constant-speed motor when the roller is at the center of the disks—that is indicating zero wind speed. As the roller nears the center of the disk, the end of the worm forces a bell crank (not shown) to open the switch and thus deenergizes the constant speed

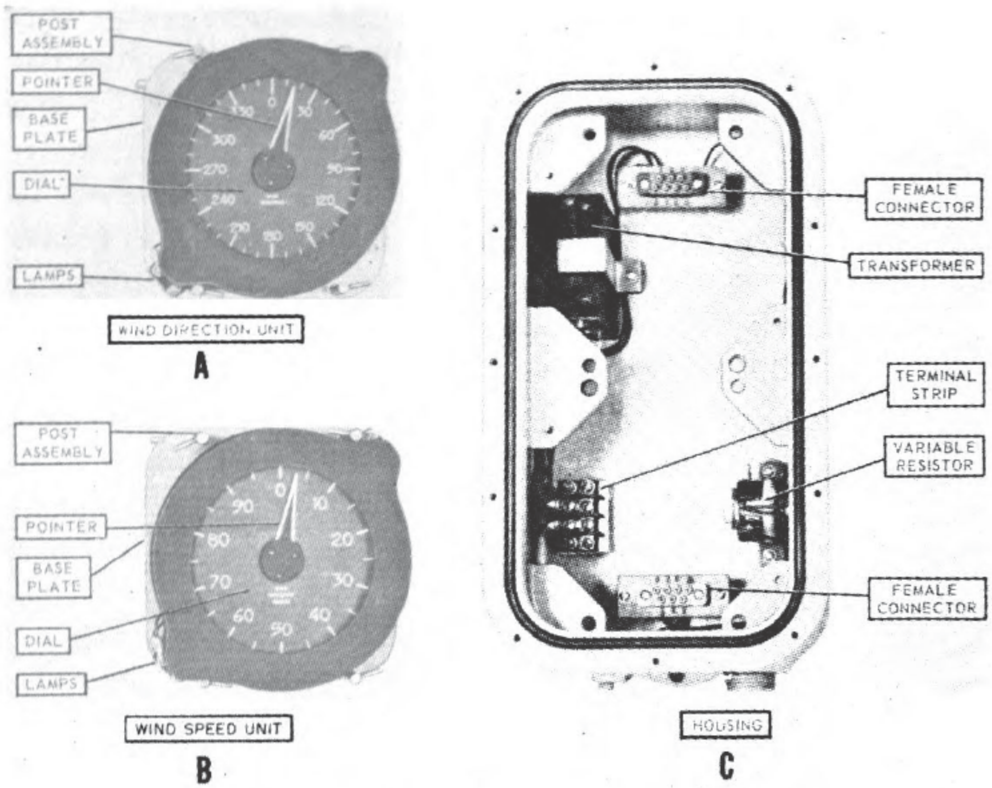


Figure 4—17.—Wind direction and speed indicator.

followup motor. This cutout save wear on the disk and roller when there is no wind speed to be indicated.

INDICATOR.—The wind direction and speed indicator (fig. 4–17) installed in the pilot house, central station, and other locations is used to indicate the wind direction and speed at these stations. This instrument consists of a (1) WIND DIRECTION UNIT (fig. 4–17A) and (2) WIND SPEED UNIT (fig. 4–17B), each mounted on individual base plates to form two complete units that are enclosed within the housing (fig. 4–17, C). The wind direction unit and the wind speed unit (fig. 4–18) are identical with the exception of the dial markings. Each has a type-1F synchro repeater that indicates on a fixed dial by means of a revolving pointer. The pointer of each unit is connected directly to its synchro shaft.

The dials are mounted on their associated base plates by means of supporting posts. They are made of a translucent material having black backgrounds with white


WIND DIRECTION AND SPEED INDICATOR
TYPE-IF SYNCHRO
TYPE-IF SYNCHRO

markings. The wind direction dial is graduated from 0° to 360° and the wind speed dial is graduated from 0 to 100 knots.

Dial illumination for each unit is provided by two lamps in parallel and a light diffuser. A 115/6-volt transformer inside the housing supplies the two dial-lamp circuits. A knob located on the housing controls a variable resistor in the lamp circuit for varying the intensity of illumination.

A typical type-B wind direction and speed indicator system installed in a large ship is illustrated in figure 4–18. This system is designed for operation on single-phase, 115-volt, 60-cycle power and a controlled-frequency circuit.

SALINITY INDICATOR SYSTEM

The salinity indicator system, circuit *SB,* is used to indicate the amount of salinity in water systems aboard ship. Salinity indicator systems are a necessity aboard ship because all fresh water, particularly when underway, is made from sea water. Excessive salinity in the boiler feed water causes pitting of the tubes and rapid deterioration due to electrolysis. Salinity indicators are usually provided in either the enginerooms or the firerooms for checking the condensate from the main and auxiliary condensers. They are also provided for the evaporator plants to indicate the degree of purity of the fresh water and condensate at various selected points in the distilling system. Salinity indicators are also being installed in submarines where distilled water is used to cool the batteries. Circuit designation 1SB is used for distilling plants, 2SB for boiler feed water systems and 3SB for submarine battery cooling water systems.

This system comprises type-D and type-E equipments. The two types are similar except that type-D equipment is provided with alarm circuits in addition to the measuring circuits. When the salinity becomes excessive, a dumping circuit is automatically activated simultaneously with the alarms to discharge the solution from the water

system. The principle of operation of both types is essentially the same. Type-D equipment is described here because the alarm circuits are an important part of the system.

The operation of the salinity indicator system is based on the principle that an increase of the electrolytic impurities (principally salt) in water increases the electrical conductivity of the water and conversely, that a decrease in the impurities increases the electrical resistance of the water.

If two electrodes are immersed in the water being tested and a constant a-c voltage is applied across the electrodes, a constant alternating current will flow provided the impurity content and the temperature of the water remain unchanged. The amount of current flow is indicated on a meter, the scale of which is graduated in GRAINS OF SALT PER GALLON, or in EQUIVALENT PARTS PER MILLION (gallons). If the saline content of the water increases for any reason because salt water leaks into the system or because the operation of the distilling plant becomes faulty, the conductivity between the electrodes increases and the meter reading increases an amount that is proportional to the increase in salinity.

Type-D Equipment

A complete salinity indicator system consists of one, or more salinity (conductivity) cells and valves, and an indicator panel. The indicator panel contains a meter and associated resistors for each conductivity cell used in the system. The meter provides a visual indication of the salinity of the water measured by its associated cell.

CONDUCTIVITY CELL AND VALVE.—The conductivity cell and valve are shown in figure 4–19.

The VALVE (fig. 4–19, A) is a standard 1¼-inch cast-bronze rising-stem gate valve rated at 200 psi hydrostatic pressure. This valve provides a means of shutting off the water when withdrawing the conductivity cell for cleaning and inspection. A shallow groove cut around the cell is

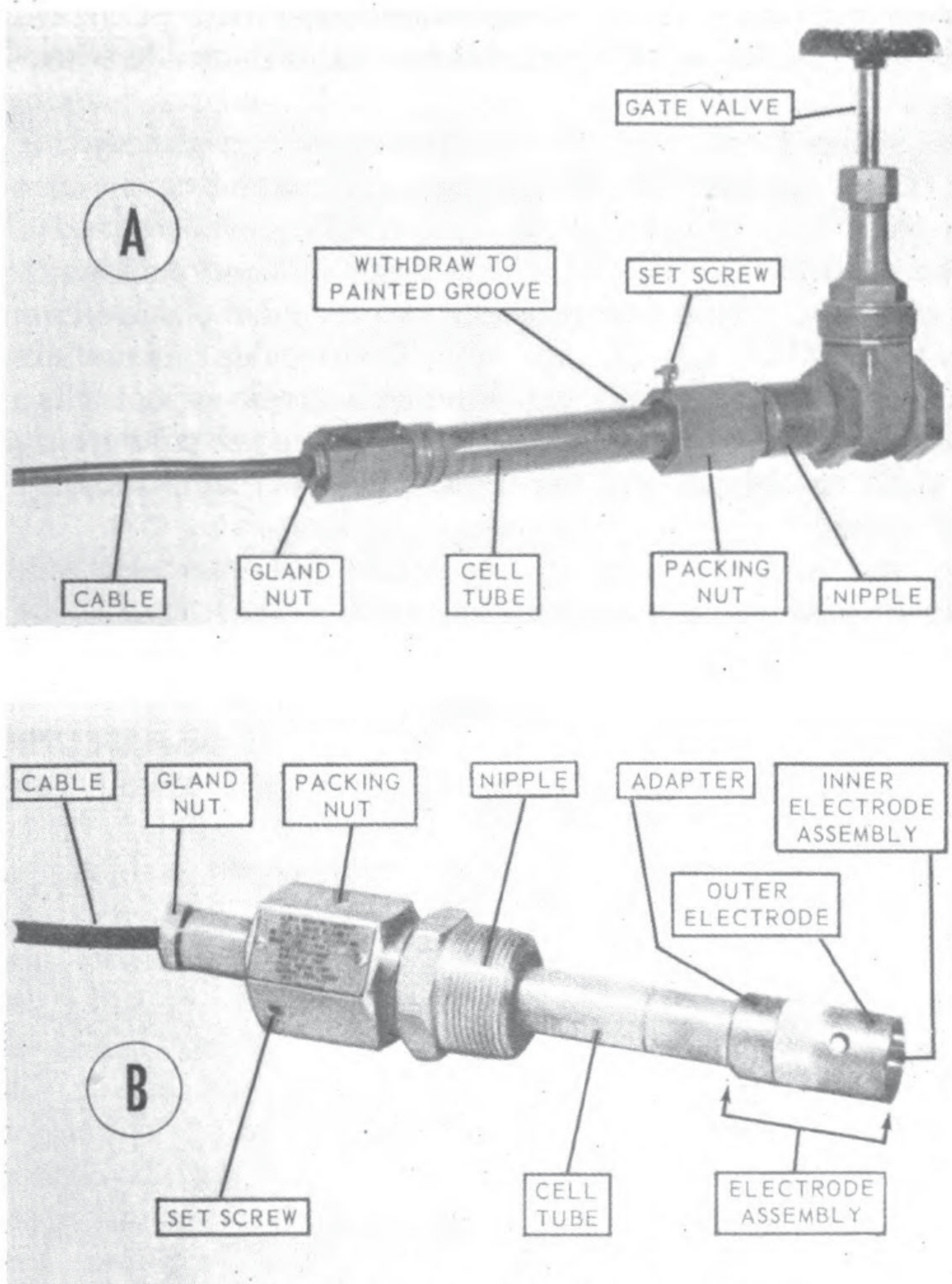


Figure 4—19.—Conductivity cell and valve.

filled with red paint to indicate the position in which the cell element should be mounted to clear the gate valve bonnet.

The TYPE-CN8 CONDUCTIVITY CELL (fig. 4–19, B) is a self-contained unit designed to operate at a maximum hydrostatic pressure of 150 psi over a temperature range of

from 40° to 250°F. The principal components of the cell are the nipple, packing nut, cell tube, and electrode assembly. The nipple threads into the valve and the packing nut threads onto the nipple to form a watertight seal.

The CELL TUBE provides a means of extending the electrode assembly through the valve. The exposed end of the cell tube is provided with a gland nut and packing, to clamp the cable in the tube and to prevent moisture from entering the cell. The incoming 3-wire cable has a white, a black, and a green conductor. The packing nut has a set screw that screws into a groove in the cell tube to prevent axial displacement of the tube by the hydrostatic pressure.

The electrode assembly comprises the inner electrode, adapter, and outer electrode.

The INNER ELECTRODE is a hollow platinum-coated brass cylinder closed at the forward end. It is held in the adapter by means of a spring-loaded nut on the end of the inner-electrode holder. A solder lug under this nut connects the white wire of the incoming 3-wire cable.

The AUTOMATIC TEMPERATURE COMPENSATOR, which is a small circular disk, is located within the inner electrode. It is made of a material having a negative temperature coefficient of resistance. This material has the same resistance-temperature characteristics as dilute solutions of sea water. One side of the compensator disk is soldered to the closed end of the inner electrode. The other side of the disk has a lead brought out through the inner electrode holder to the black wire of the incoming cable.

The OUTER ELECTRODE is a hollow brass cylinder, the inside of which is coated with a thin layer of platinum. This electrode screws onto the adapter which in turn screws onto the cell tube. The threads of these components are painted with a sealing compound prior to assembly to obtain watertight joints. The connection for the outer electrode is made by soldering the green wire of the incoming 3-wire cable into the hole provided in the

cell tube. This connection is not shown in the figure because it lies beneath the packing nut.

INDICATOR.—The indicator panel (fig. 4–20) is designed for operation with four type-CN8 conductivity cells and has a self-contained power supply and alarm circuits in addition to the metering circuits. The incoming cable is brought through a steel plate at the bottom of the housing and is connected to two terminal strips located above the terminal plate.

The components mounted on the housing cover include four meters of the power-factor type and four test switches, one for each cell circuit. Each cell circuit has an alarm light, bell cutout light, and bell cutout switch. Cell circuits 3 and 4 also have lights to indicate dumping valve operation. There is only one alarm bell and it is common to all circuits and operates in conjunction with the bell circuits of the four cells. A power-on pilot light and two fuse-holder-and-indicator combinations are also mounted on the cover.

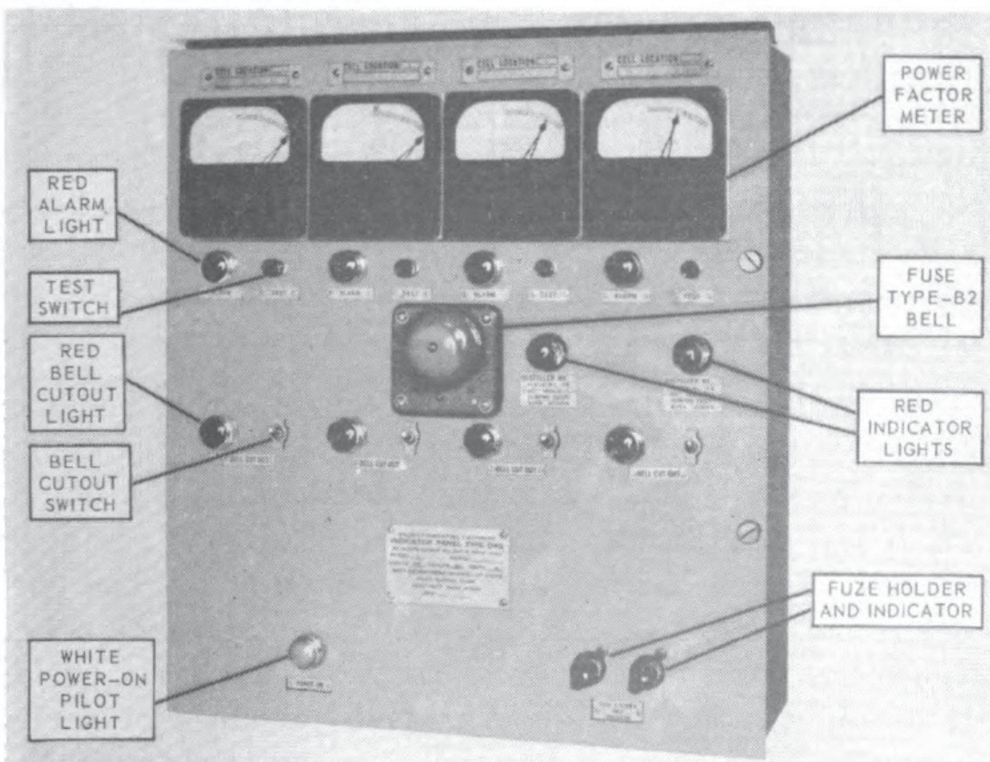


Figure 4—20.—Indicator panel for type-D salinity indicator system.

The components mounted on the chassis inside the housing include the coupling transformer, alarm relays, electron tubes, and bell relay. Below these are located the alarm and calibrating controls and the two dumping relays. At the bottom are the power transformer and two terminal strips.

The salinity indicator measures the electrical conductivity of the water. These conductivity values are then converted into equivalent concentrations of sea water. A simplified schematic diagram of the salinity indicator is shown in figure 4–21.

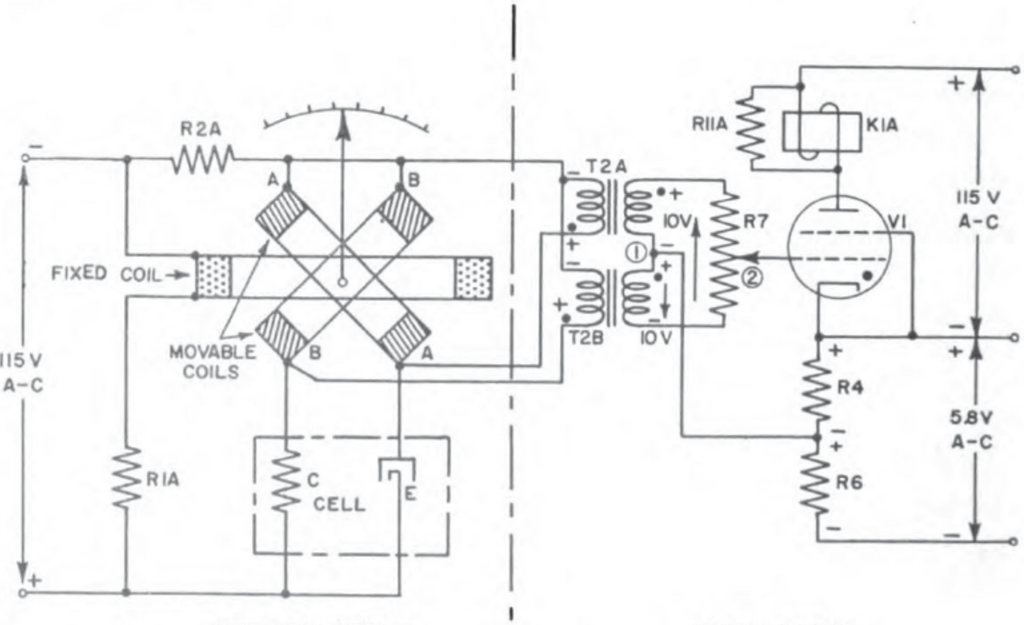


Figure 4—21.—Simplified salinity indicator schematic diagram.

The INDICATOR CIRCUIT consists of a bridge that includes a special power factor type of meter having both fixed and movable members. The movable member has two windings, A and B, at right angles to each other and arranged so that it is free to turn within the fixed coil. The currents in both movable coils are in phase with each other because the coils are energized from the same a-c power source and the circuits are resistive (because of series limiting resistor R2A). The movable coils turn until the resultant field lines up with the field of the fixed coil.

Hence, the meter indication is directly dependent on the resultant field of the movable coils, which in turn is dependent on the ratio of the currents in the movable windings. This indication is independent of voltage changes and of reasonable frequency changes of the power supply because there is no iron in the meter magnetic circuit and because the three circuits containing the coils are essentially resistive.

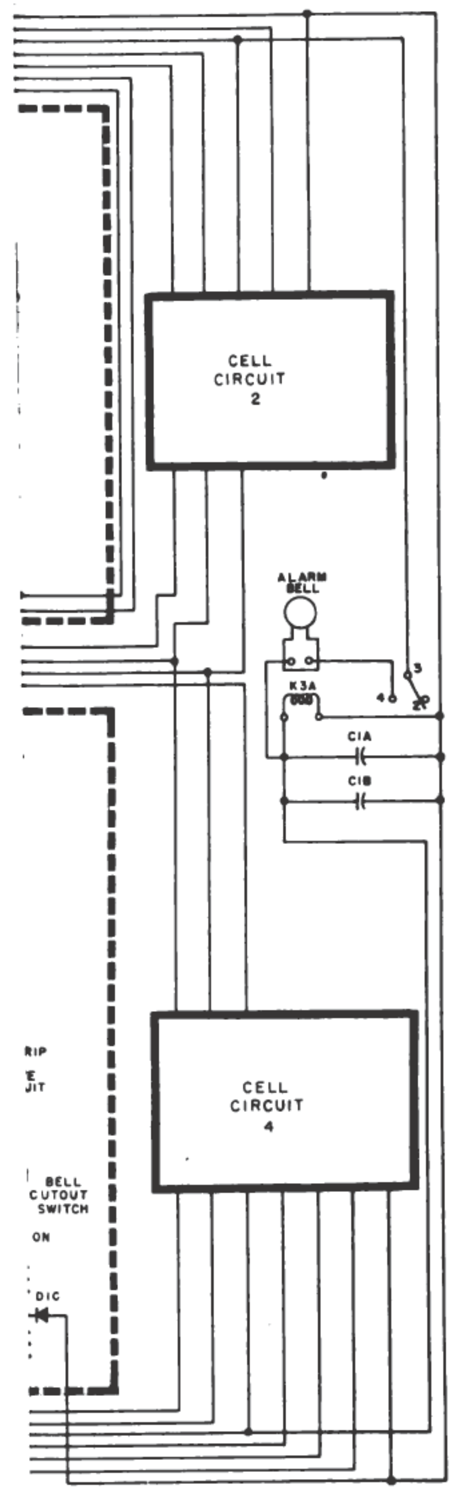
The fixed coil is energized from a 115-volt secondary winding of power transformer *T*1 (not shown in the figure) in series with a voltage-dropping resistor, *R*1*A*. The bridge circuit is also supplied from this secondary and is fed through limiting resistor *R*2*A* to the common connection point of the crossed movable windings. It is apparent that the currents in these two windings are proportional to the two loads. These loads are the automatic temperature compensating resistor, *C*, (contained within the cell) in series with coil *B* and the resistance of the water being measured by the electrodes, *E*, in series with coil *A*. The meter reading is therefore determined by the ratio of the water resistance to the compensator resistance.

There is only one possible meter reading at any given salinity and temperature. If the temperature is either raised or lowered from this point, the meter reading will remain unchanged because of the action of the compensator even though the water resistance may change appreciably. This temperature compensation occurs because any thermal change of the water being measured by the cell is immediately transferred to the automatic compensator. The resistance of the compensator is inversely proportional to its temperature so that the thermal change transmitted to the compensator, through the cell walls, causes its resistance to change accordingly. The resistance-temperature characteristics of the compensator are the same as those of dilute solutions of sea water. Therefore, the thermal change in the compensator, which is exactly the same as the thermal change of the sea water, causes sufficient resistive change in the compensator to

compensate for the resistance change occurring in the cell. Although the absolute values of current in the windings have changed, their ratio has not changed and hence the meter reading is unchanged. Because temperature compensation is equally effective at all salinities, the only change that can vary the meter reading is a change in the current ratio caused by a change in salinity.

The ALARM CIRCUIT is coupled to the indicator circuit by means of transformers *T2A* and *T2B* (fig. 4–21). The primary of *T2A* is connected across movable coil *A* and the primary of *T2B* is connected across movable coil *B*. Thus the voltages developed across coils *A* and *B* are impressed across the primaries of the step-up transformers *T2A* and *T2B* respectively. The secondaries of these transformers are connected in series (aiding) with each other and with potentiometer *R7* as a common load. The control grid of thyratron *V1* is connected to the sliding contact of the potentiometer. The midpoint of the transformer secondaries is connected to a bleeder, consisting of *R4* and *R6*, which is supplied from the 5.8-volt winding of power transformer *T1* (not shown in the figure). The voltage across *R4* biases *V1* to cut off for the condition of no output voltage from *T2A*. The secondaries of *T2A* and *T2B* form a bridge circuit with the upper and lower portions of *R7* in the grid input circuit of *V1*.

The output voltage between points ① and ② is in series opposition to the bias voltage across *R4*. Before the salinity cell is immersed in water, *R7* is adjusted so that the bias exceeds cutoff and thyratron *V1* does not conduct. When the cell is immersed in water the output voltage of *T2A* increases the current through *R7* and the output voltage between points ① and ② increases. This voltage is applied between the grid of *V1* and the common connection between the bleeder resistors, *R4* and *R6* (the effect of which is to lower the resultant control grid voltage). The magnitude of the resultant voltage applied to the grid is determined by the potentiometer setting. Hence, the



CELL
CIRCUIT
2
ALARM
BELL
K3A
C1A
C1B
CELL
CIRCUIT
4
RIP
BELL
CUTOUT
SWITCH
ON
DIC

em.

control grid voltage, and therefore the tube conduction, depends upon the salinity of the water in the cell. When *V*1 conducts, relay *K*1*A* in the plate circuit operates and energizes visual and audible alarm circuits. After *V*1 begins conducting, the relay shading slug and resistor *R*11*A* keep relay *K*1*A* energized during the negative half cycles when *V*1 is nonconducting.

Proper circuit operation depends upon the correct phase relations between the various components. Tube *V*1 conducts only during the positive half cycles of applied voltage. Assume the instantaneous polarities are as indicated (fig. 4–21). As the salinity rises (cell resistance decreases) the current through, and the voltage across, winding *A* increases. Thus, a higher positive voltage is impressed on the control grid, causing *V*1 to conduct and to energize relay *K*1*A*, which actuates the alarm circuit. Under these conditions the dumping solenoid is deenergized and the dumping valve opens to permit the tank solution to be discharged from the system.

A type-D salinity indicator system is shown in figure 4–22. Because cell circuits 1 and 2 are identical, only cell circuit 1 is shown in detail. Cell circuit 2 is indicated by the block diagram at the upper right. When relay *K*1*A* in cell circuit 1 is energized, red alarm light *I*1*B* is turned on. When bell-cutout switch *S*2*A* in cell circuit 1 is in the ON position as indicated provided relay *K*1*A* is energized, the mixing circuit consisting of *R*8*A*, *R*9*A*, and *D*1*A* is energized and bell *B*1 rings. The mixing circuit allows the bell alarm to be operated by all the alarm circuits (bell cutout switches in the ON position) or it allows the other external alarms (bell cutout lights) to be operated by a specific alarm circuit (bell cutout switches in the OFF position). When the mixing circuit is energized, part of the voltage is rectified by the germanium diode, *D*1*A*, and operates relay *K*3*A*, which energizes the bell alarm. Capacitors *C*1*A* and *C*1*B* hold *K*3*A* in the energized position during the nonconducting half cycles of *D*1*A*. When

bell cutout switch *S2A*, is in the OFF position, no power is applied to the mixing circuits and bell cutout light *I1A* is energized at all times.

Because cell circuits 3 and 4 are identical, only cell circuit 3 is shown in detail. Cell circuit 4 is indicated by the block diagram at the lower right. However, circuits 3 and 4 differ from circuits 1 and 2 in their wiring and external alarms. *V3* is made to operate at the half cycle of voltage opposite to the half cycle on which *V1* operates by interchanging the power connections to the plates and cathodes and by reversing the primary leads of coupling transformers *T2E* and *T2F* with respect to those of *T2A* and *T2B*. The phase of the signals applied to the thyratron control grids is thus shifted 180° to correspond to the 180° shift of plate voltages. By operating one half of the thyratrons on one alternation and the other half on the next alternation a more balanced load is presented to power transformer *T1*.

When relay *K1C* in cell circuit 3 operates, red alarm light *I1F* in cell circuit 3 is energized. Bell-cutout light *I1E* continues to operate as long as bell-cutout switch *S2C* is in the OFF position. The dumping valve relay *K2A* in cell circuit 3 is also energized except when the test switch is operated. Test switch *S3A* in cell circuit 3 is shown in the normal unoperated position. Pressing this switch inserts precision resistor *R5C* in the meter circuits and opens the leads to the dumping valve relay coil *K2A* in order to avoid false dumping due to testing. Each cell-testing resistor has a resistance equal to that of the cell when immersed in a solution having a salinity of 1 grain per gallon of water at a temperature of 110° F. Dumping relay *K2A* has one pair of normally closed double contacts that are connected to the unfused 115-volt power source to the indicator panel to supply the dumping solenoid terminals. The dumping valve indicator circuit is also supplied from this source.

Under normal conditions (not dumping), power is ap-

plied to the primary of transformer *T3A* in cell circuit 3 through bimetallic strip H1A, and the indicator lights *I2A* and *I2B* are normally ON. Under dumping conditions the dumping solenoid valve is deenergized by energizing dumping relay *K2A* through the closure of relay *K1C*. When the dumping solenoid is deenergized, switch S in the dumping solenoid circuit is closed. This action completes a circuit from the heating unit of flasher *H1A* across the line. The heat from the unit causes the bimetallic element to bend away from its contact and open the primary of transformer *T3A*, disconnecting the power from the coil and the indicator lights *I2A* and *I2B*. The coil then cools until the flasher contacts close again, causing the operation to repeat. While dumping occurs, indicator lights *I2A* and *I2B* operate at from 20 to 30 flashes per minute.

The complete circuit from the meter indication to the external alarms can be checked at any time by means of the test switches provided on each circuit. Pressing the test switch causes the meter to read 0.261 equivalent parts per million (epm) and the thyratron to fire. The red alarm light and bell are energized in any circuit being tested the same as for a normal alarm. However, the dumping relay associated with circuit 3 does not operate falsely because it is open-circuited when test switch S3A is in the operated position.

The meter circuits are calibrated to read 0.261. This calibration should be checked once each month by pressing the test switch and reading each meter. Movable coils *A* and *B* in cell circuit 1 are shunted by resistors *R3A* and *R4B* respectively. If *R3A* and *R4B* had equal resistance they would not affect the meter reading. However, *R3A* is an adjustable resistor having a maximum resistance 2½ times that of fixed resistor *R4B*. Thus, *R3A* can be varied to obtain a higher or lower meter reading than normally when *R3A* and *R4B* are equal. For calibration purposes the cell must be immersed into a solution of known salinity. This condition is simulated by a wire-

wound resistor, *R4B*, having a tolerance of ±½ percent, which is the exact electrical equivalent of a 0.261-epm solution. Pressing test switch *S1A* transfers the meter windings from the cell connections to the calibrating resistor. The meter can be set to read exactly 0.261 epm by adjusting *R3A*. Releasing test switch *S1A* restores the normal operating position by returning the meter windings to the cell connections. This one adjustment calibrates the entire circuit for any combination of salinity and temperature.

The alarm circuits should be checked for proper operation once each month by pressing the test switches and observing the alarms. They should be set to 0.065 epm. In cell circuits containing a dumping relay the cell must be removed from the valve and the cell test resistor substituted for the outer electrode because pressing the test switch disconnects the dumping relay. This action causes a salinity reading in excess of about 0.261 epm and operates all the alarms of the circuit. Operation of the dumping relay must be observed at its remote location. About 30 seconds are required for the dumping indicator on the panel to start flashing.

To reset or check an alarm point, prepare a dilute salt solution of the same salinity as the desired alarm point and use the meter and the cell to measure the salinity. For satisfactory results the saline solution and the cell must be at the same temperature. For convenience in setting the alarm, the cell can be connected directly to the proper terminals on the panels instead of being connected at its remote location.

UNDERWATER LOG SYSTEM

The underwater log system, circuit *Y*, is used to measure and indicate the speed of the ship and the distance traveled through the water. It transmits these indications to the various fire control and navigational equipments as required by the particular type of ship.

The general types of underwater log equipments in-

stalled in naval vessels are the (1) pitot-static, or hydraulic, type and (2) propeller type.

The PITOT-STATIC, or HYDRAULIC, type of equipment consists essentially of (1) a rodmeter that can be raised or lowered through the hull of the ship for securing or operational purposes, and (2) a mechanism within the ship that converts the pressure signals received from the rodmeter into indications of speed and distance traveled.

The pitot-static underwater log system comprises type-RB40 and type-RB25 equipments. Type-RB40 is installed in large combatant ships and type RB25 equipment is installed in small surface ships and submarines. Only type-RB40 equipment is discussed because the principle of operation of both types is essentially the same.

The PROPELLER type of equipment consists essentially of a rodmeter that can be raised or lowered through the hull of the ship for securing or operational purposes and supports a small impeller-driven reluctance type of generator. This generator generates a voltage at a frequency directly proportional to the speed of the propeller. Because the speed of the propeller and the frequency of the propeller generator are directly proportional to the ship's speed, this frequency can be converted into indications of ship's speed and distance traveled.

Type-RB40 Equipment

A typical type-RB40 underwater log system consists of a rodmeter, sea valve, rotary distance transmitter, and control unit all installed in the hull; a master speed indicator in the I. C. room; combined speed and distance indicators in the pilot house, central station, and flag plot and other required spaces; and speed indicators in the main battery plotting room and in the aerological office.

Selector switches are installed on the A.C.O. switchboard for selecting the various indicator stations and the speed inputs to the fire control switchboard and to the forward and after gyrocompass switchboards.

The hydraulic installation of the underwater log system shown in figure 4–23 consists of the rodmeter, sea valve, rotary distance transmitter, and control unit.

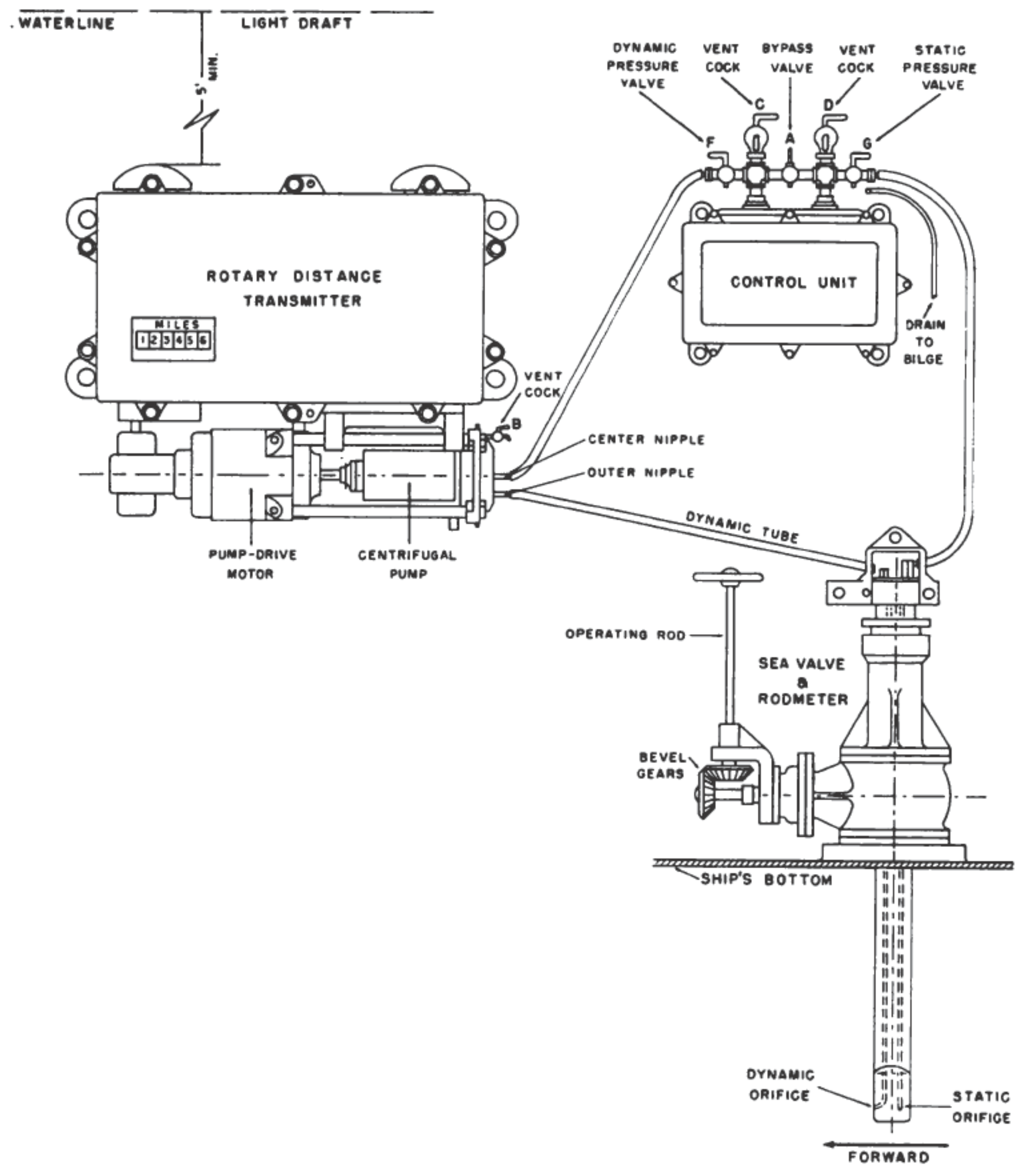


Figure 4—23.—Hydraulic installation of underwater log system.

RODMETER AND SEA VALVE.— The RODMETER is installed as close to the keel as possible and mounted at the turning point of the ship which is normally in the forward one-third portion. The rodmeter is made of manganese bronze having an oval cross section with a flat tip at its extreme lower end. A dynamic orifice in the leading edge of this

flat tip is connected to a pitot tube that terminates in a nipple at the upper extremity of the rodmeter. Two static orifices, one in each side of the tip, are connected to a common tube that also terminates in a nipple at the upper end of the rodmeter (fig. 4–23). A guard and clamp assembly protects the nipples and provides a means for positioning and securing the rodmeter in its housed position.

The SEA VALVE, through which the rodmeter passes, is a 3-inch bronze gate valve bolted to the skin of the ship. An extension attached to the top flange of the valve provides the upper support for the rodmeter when it is projected through the valve. The bottom of the sea valve is fitted with a cast bronze spigot that guides the rodmeter and forms the lower support. The valve is operated by a handwheel and rod which is bevel-geared to the stem of the valve. Thus, the rodmeter can be lowered through the sea valve below the hull into its operating position, or raised through the sea valve into its secured position.

In its operating position the rodmeter is projected through the sea valve and beyond the hull into water relatively unaffected by the motion of the ship. When the ship is stationary, pressure due to the height of water from the rodmeter orifices to the ship's water line, or the STATIC PRESSURE, is exerted equally on both the static and dynamic orifices.

When the ship moves forward, the passage of the rodmeter through the water produces an additional pressure at the dynamic orifice. Therefore, the pressure at the dynamic orifice is the sum of the DYNAMIC PRESSURE due to the forward motion and the prevailing STATIC PRESSURE. The forward motion of the rodmeter has very little effect on the pressure exerted at the two static orifices because these orifices are on the flat portion of the tip at right angles to the flow of water. The static pressure is equal at both the dynamic and static orifices. The difference between the pressures at the dynamic orifice and the static orifices is the DIFFERENTIAL PRESSURE, which is proportional to the square of the ship's speed. When the ship

backs down, the passage of the rodmeter through the water does not produce a pressure at the dynamic orifice and consequently no differential pressure results.

Whenever the ship's draft changes, the static pressure changes equally in both the static and dynamic lines and thus does not affect the pressure difference (differential pressure). The pressure from the dynamic orifice is transmitted to the outer nipple of the pump in the rotary distance transmitter, and the pressure from the static orifices is hydraulically transmitted to the control unit.

ROTARY DISTANCE TRANSMITTER.—The rotary distance transmitter (fig. 4–24) is mounted on a fore-and-aft bulkhead near the rodmeter and sea valve. Its function is to provide a rotary motion proportional to the ship's speed. This rotary motion is converted in the master speed indicator into an angular displacement on a dial. This instrument comprises an automatically controlled motor-driven centrifugal pump, distance transmitting unit, and a motor-driven autotransformer called a transtat assembly.

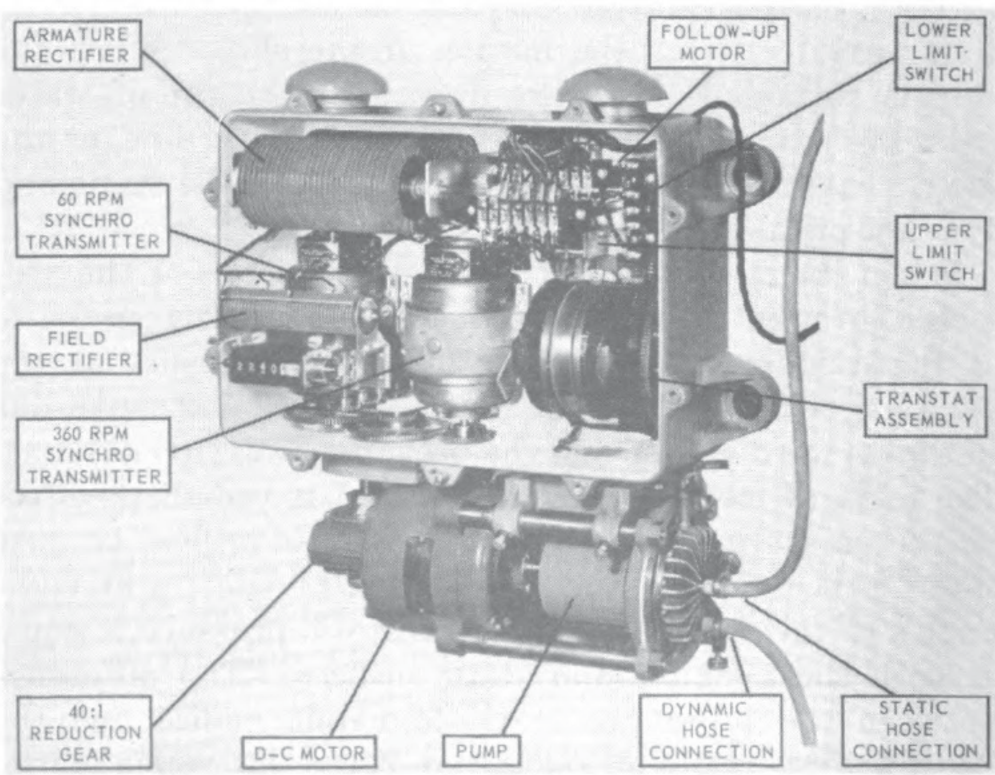


Figure 4—24.—Rotary distance transmitter of underwater log system.

The PUMP consists of a radially bladed impeller rotating in a cast bronze housing with a monel liner. The pump housing is a monel casting having a center and an outer nipple for the hydraulic connections. The impeller shaft is mounted on ball bearings and is driven by a d-c motor.

The D-C MOTOR is a compound motor with interpoles. The armature shaft is mounted on ball bearings, one end of which extends through a coupling to the shaft of the centrifugal pump. The other end of the armature shaft drives (through reduction gears) the distance transmitting unit and a counter that registers distance in units of 1/100 nautical mile. The pump and motor assembly is mounted on the bottom of the instrument housing.

The DISTANCE TRANSMITTING UNIT (fig. 4–28) consists of two synchro transmitters. One synchro transmits rotary motion to the master speed indicator, which in turn retransmits this motion to the speed and distance indicators at the rate of 60 revolutions per mile. The other synchro transmits rotary motion to the dead reckoning analyzer at the rate of 360 revolutions per nautical mile.

The TRANSTAT ASSEMBLY comprises a motor-driven autotransformer that delivers a variable a-c voltage (from 0 to 185 volts) to the armature rectifier, which in turn supplies a d-c voltage to the armature of the pump-drive motor. The rotating brush arm of the transtat, which varies the rectifier voltage and hence the d-c armature voltage, is positioned by a followup motor. The followup motor is controlled by contacts located in the control unit. Two normally closed limit switches are provided to prevent overtravel of the brush arm. A field rectifier supplies a steady d-c voltage to the field of the pump-drive motor.

CONTROL UNIT.—The control unit (fig. 4–25) is mounted next to the rotary distance transmitter. It consists of a watertight bronze housing containing two sensitive hydraulic bellows that operate a contact mechanism through a pivoted balance bar. The right-hand bellows is con-

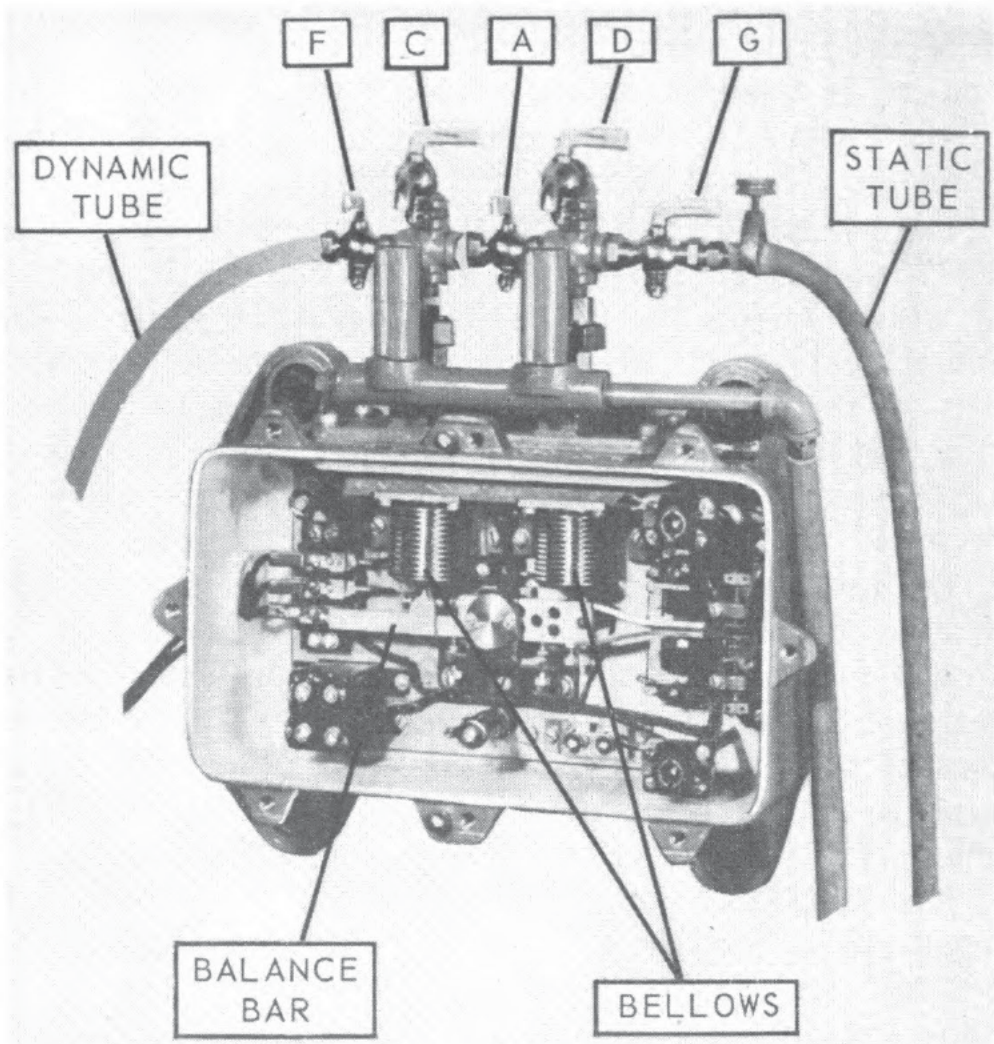


Figure 4—25.—Control unit of underwater log system.

nected hydraulically to the static pressure nipple of the rodmeter; whereas, the left-hand bellows is interconnected hydraulically with the center nipple of the centrifugal pump in the rotary distance transmitter. Contacts attached to springs on the end of the balance bar control the operation of the transtat followup motor in the rotary distance transmitter. Vent cocks *C* and *D* and bypass valve *A* are provided for the purpose of clearing the air from the hydraulic system.

The operation of the rotary distance transmitter and the control unit are considered together because the functions of these instruments are interdependent. Assume

that the ship is stationary and that the rodmeter is projected from the hull with the entire hydraulic system filled with water and all valves in their operating positions. Also, assume that the electrical system is energized, that the rotating brush arm of the transtat is at the low-voltage (left) end of its winding, and that the normally closed (lower) limit switch is open. Under these conditions the pump-drive motor will not rotate the centrifugal pump and the pressures in the two bellows in the control unit will be equal.

When the ship moves forward, the passage of the rodmeter through the water produces in the dynamic orifice a pressure that adds to the static pressure. This dynamic pressure passes through the rotary pump (impeller not rotating) to the left-hand bellows in the control unit, producing a greater pressure in this bellows than that existing in the right-hand bellows. The pressure difference expands the left-hand bellows and raises the contact arm until it closes the upper contact, *A* (fig. 4–28). Current now flows through lower magnet coil *A* and through the increase-direction shading coil of the followup motor in the rotary distance transmitter (fig. 4–28). The followup motor now starts operating in a counterclockwise direction, moving the rotating brush arm of the transtat toward the high voltage end of its winding. As soon as the brush arm starts to move, the (lower) limit switch closes and, when the armature voltage is high enough, the pump-drive motor starts to drive the impeller at a slow, gradually increasing speed.

The rotation of the impeller produces a pressure that opposes the dynamic pressure received from the rodmeter. When this action reduces the pressure in the left-hand bellows to the value of the static pressure in the right-hand bellows, the balance bar will move to its central position and open the contact at *A*. The followup motor now stops driving upward, positioning the transtat arm with a slight hunting motion, thereby causing the pump-

drive motor and the impeller to run at a substantially constant speed.

Whenever upper contact *A* in the control unit is closed, the lower magnet coil, *A*, is energized and tends to open the contacts by attracting the magnet armature on the balance bar. If the pressure difference between the two bellows is excessive, the magnet exerts insufficient force to open the contacts, but as the speed of the pump impeller increases to the point where the pressures in the bellows are about equal, the magnet opens the contacts. Because the magnet is then deenergized, the contacts immediately close again and then, under the influence of the magnet, open again. This action serves to slow down the operation of the followup motor (which drives the brush arm of the transtat) near the end of the adjustment, and also tends to reduce the effect of friction in the bearings of the balance bar. The upper magnet coil, *B*, operates similarly in conjunction with the lower contact, *B*. The action of these magnet coils reduces the hunting in the speed of the pump impeller to a point where it is not objectionable.

When the ship's speed decreases, the pressure developed at the dynamic orifice of the rodmeter will be reduced. The pressure developed by the rotation of the pump impeller opposing the dynamic pressure will then exceed this pressure, causing the left-hand bellows to contract. This contraction lowers the contact arm, thereby closing the lower contact, *B*, in the control unit. This action completes the circuit through the decrease-direction shading coil of the followup motor. This motor then drives the brush arm of the transtat toward the low-voltage end of its winding, thereby reducing the speed of the pump-drive motor and of the impeller.

There is no flow of water through the pump beyond the small amount required to actuate the bellows. The pump produces a pressure that opposes the dynamic pressure from the rodmeter. When the pump impeller reaches a steady speed sufficient to balance the dynamic pressure

from the rodmeter, the pressures in the two bellows will be equal because both bellows are subjected only to static pressure. The balance bar is now in its central position and opens the contact at *B*.

It is obvious from the foregoing that the speed of the pump-drive motor is continuously and automatically controlled so that the pressures in the two bellows are always equal, regardless of variations in the ship's speed and consequent variations in the differential pressure developed at the rodmeter. Because the pressure developed by the pump impeller is proportional to the square of the speed of the pump, and because the dynamic pressure from the rodmeter is proportional to the square of the ship's speed, the speed of the pump impeller is directly proportional to the speed of the ship. The pump is designed so that its impeller rotates at 9,000 revolutions per nautical mile traveled by the ship. This speed of rotation of the impeller corresponds to 6,000 revolutions per minute for a ship's speed of 40 knots.

MASTER SPEED INDICATOR.—The master speed indicator (fig. 4–26) receives the rotary motion proportional to the distance traveled by the ship from the 60-revolutions-per-mile transmitter in the rotary distance transmitter. This input is combined by means of the time element, derived from the controlled-frequency supply, into an instantaneous indication of the ship's speed in knots. This speed indication is transmitted to the speed and distance indicators and to other stations in the ship. The ship's speed is indicated by a pointer on the circular dial that is graduated from 0 to 40 knots. The counter is of the digital type and registers the distance traveled in units of 1/100 nautical mile.

This instrument consists of a friction disk and roller assembly that is identical to the assembly described in the chapter on basic mechanisms. The synchro repeater in this assembly (fig. 4–28) is electrically connected to the 60-revolutions-per-mile transmitter in the rotary distance transmitter and thus rotates at 60 revolutions per mile.

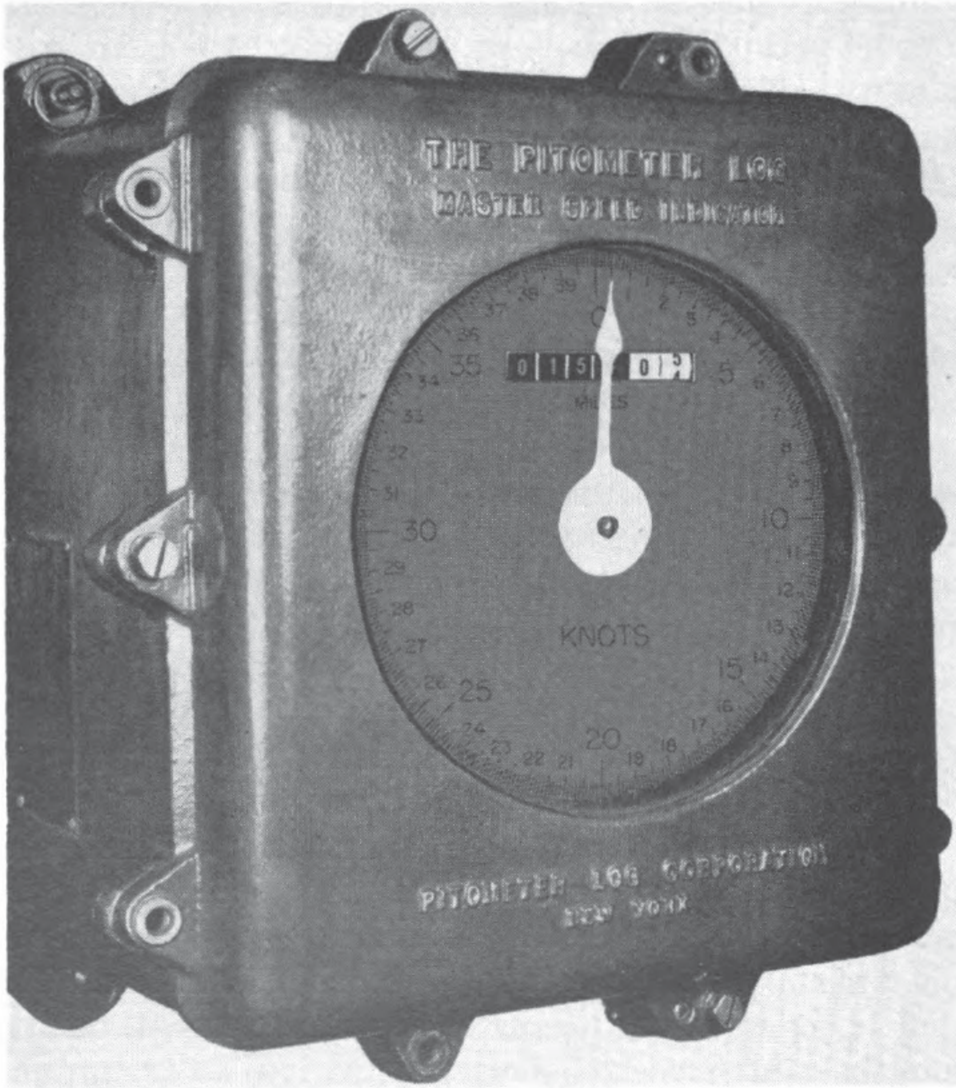


Figure 4—26.—Master speed indicator of underwater log system.

An extension of the repeater shaft drives the counter through a 6:1 gear ratio. Hence the counter rotates at the rate of 10 revolutions per mile. As the counter turns up "10" per revolution, it registers nautical miles traveled by the ship in units of 1/100 mile.

The synchronous motor in this assembly is energized from the 60-cycle, controlled-frequency supply and its slow-speed shaft rotates at exactly 100 revolutions per minute in a clockwise direction.

The synchro transmitter is geared to the pointer shaft at a 1:1 ratio so that its rotor makes 1 complete revolution

for 1 revolution of the pointer. This synchro transmits ship's speed to the speed and distance indicators and to other stations in the ship.

SPEED AND DISTANCE INDICATOR.—The speed and distance indicator (fig. 4–27) repeats the speed readings of the master speed indicator and registers the distance traveled on a mechanical counter. This instrument consists of a type-5F and a type-1F synchro repeater mounted on a common base plate to form a complete internal unit.

The type-5F repeater is electrically connected to the synchro transmitter in the master speed indicator (fig. 4–28). The indicator pointer and hub are connected directly to an extension of the repeater shaft at the center of the dial. This pointer indicates the speed on the dial,

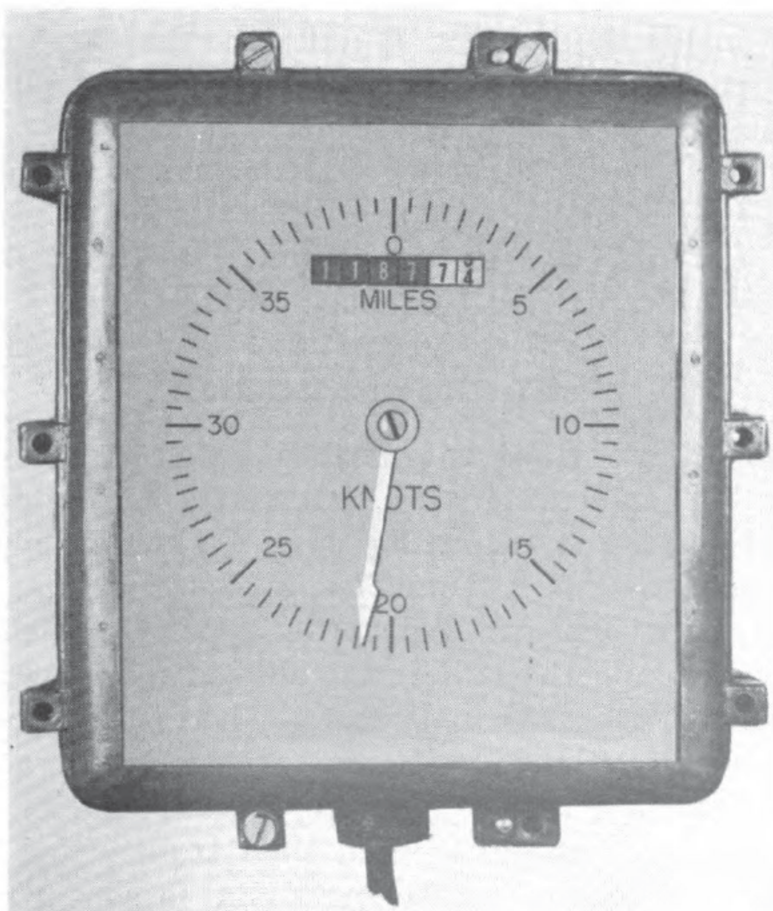


Figure 4—27.—Speed and distance indicator of underwater log system.

which is graduated from 0 to 40 knots in 1/10-knot increments.

The type-1F repeater is electrically connected to the 60-revolutions-per-mile transmitter in the rotary distance transmitter (fig. 4–28) and thus rotates at the rate of 60 revolutions per mile. This repeater drives, through reduction gears at a 6:1 ratio, the distance indicator located at the top of the dial. As the counter indicates "10" per revolution and as its drive shaft rotates at the rate of 10 revolutions per mile, it will register the distance traveled by the ship in units of 1/100 mile.

Dial illumination is provided by three lamps located around the perimeter of the dial. A clear plexiglas distributor plate attached to the inside of the cover collects the light rays from the lamps and distributes the light evenly over the dial graduations. A 115/6-volt transformer inside the housing supplies the dial-lamp circuit. The intensity of illumination is controlled by means of a variable resistor in series with this circuit.

A typical type-RB40 underwater log system installed in a large ship is shown in figure 4–28. This system is designed for operation on single-phase, 115-volt, 60-cycle power and a controlled-frequency unit.

Propeller Type of Equipment

The propeller type of equipment is an electromechanical system for indicating the ship's speed and distance traveled and for transmitting this information by means of synchros to other remotely located instruments.

The system consists of a propeller type of rodmeter that projects through the hull of the ship, a rodmeter amplifier, and a transmitter-indicator. The distance traveled is measured by the rodmeter in terms of voltage cycles. The voltage signal is transmitted to the rodmeter amplifier where it is amplified, and then transmitted to the transmitter-indicator where the signal is converted into distance and speed values. These values are visually

indicated and are transmitted by means of synchros to other devices in the ship.

This system is designed for operation on single-phase, 115-volt, 60-cycle power and a controlled-frequency circuit.

RODMETER AND SEA VALVE.—The rodmeter and sea valve assembly is shown in figure 4–29. The RODMETER consists of a propeller assembly, which is a complete unit mounted on a rod by means of a single stud and anchor nut.

The propeller assembly (fig. 4–29, A) is the distance measuring element. It comprises a four-bladed propeller that drives a 2-phase, reluctance-type generator housed within the hub of the propeller. This generator consists of a stationary permanent magnet and a 2-phase armature winding. The magnetic circuit includes a rotating inductor that varies the flux through the armature windings and produces the equivalent output of an 8-pole generator.

The propeller shaft, which is made of corrosion-resistant steel, is supported by two radial bearings. A thrust washer (not shown) receives the end thrust caused by the forward motion of the ship. A male connector at the top of the propeller assembly and a female connector at the bottom of the rod provide electrical connections between the propeller assembly and rod.

The rod (fig. 4–29, A) is designed for use with a 3-inch sea valve. It is made of bronze and consists of a tube section and a cap section.

The lower end of the tube section serves as a mounting base for the propeller assembly and is installed in the sea valve. A 3-wire cable is threaded through the tube section and imbedded in wax. This cable connects a female connector in the lower end of the tube to a connector in the upper end of the tube.

The cap section is secured to the tube section by screws and provides a means of locking the rodmeter in the normal operating position. The incoming cable from the rodmeter amplifier is brought into the cap through a

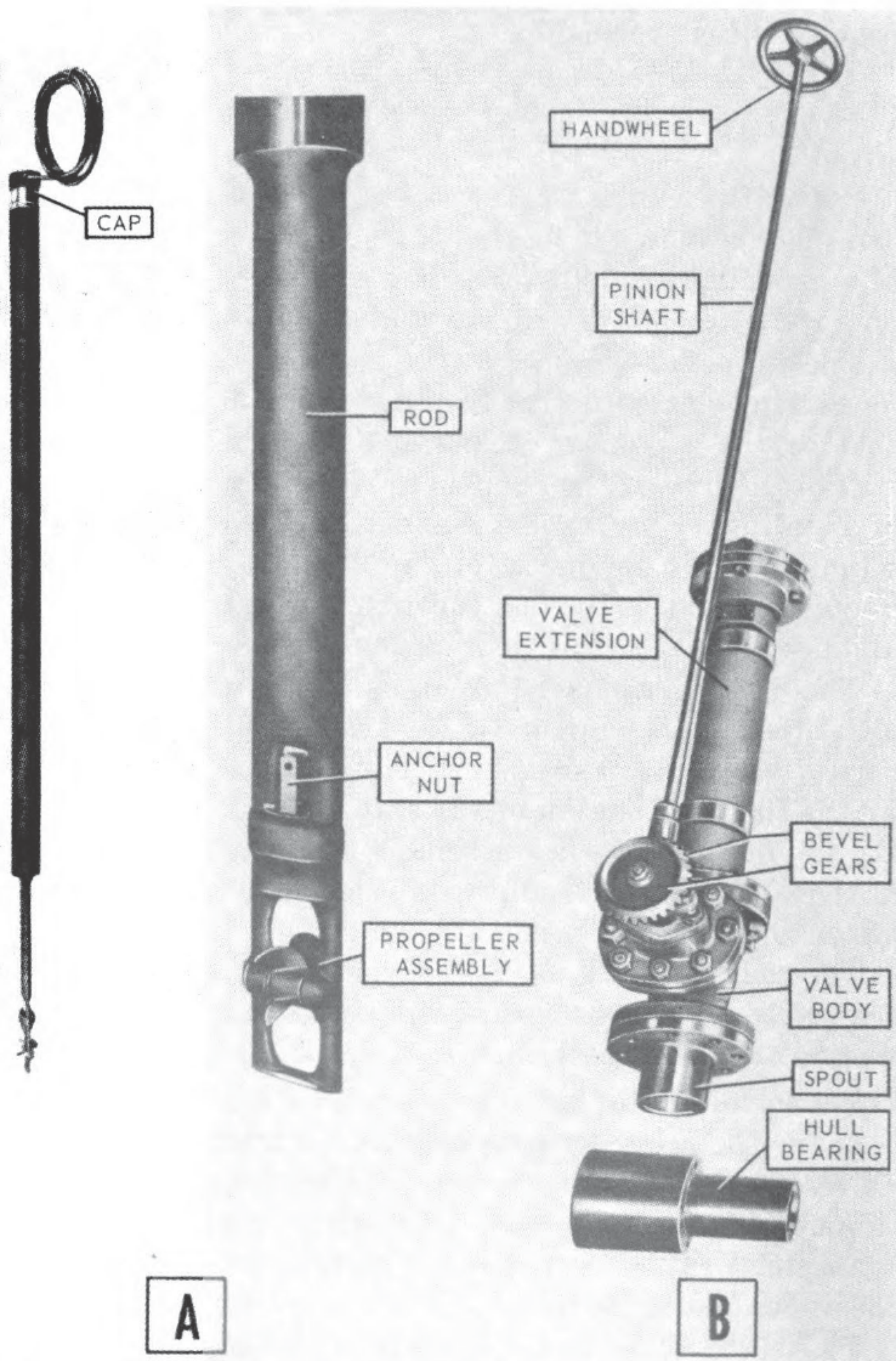


Figure 4—29.—Rodmeter and sea valve of propeller type of underwater log system.

watertight terminal tube and connects to a terminal strip in the top of the cap.

The SEA VALVE (fig. 4–29, B) is essentially a gate valve provided with an extension on the inboard end. It is designed for projecting the rodmeter below the hull of the ship and for withdrawing the rodmeter in its secured position. The rodmeter is lowered and raised similarly to the type-RB40 rodmeter previously described. The valve is operated by a handwheel attached to a shaft. A separate hull bearing is provided to support the rodmeter when it is extended through the hull of the ship.

The propeller assembly, when extended below the hull of the ship in its normal operating position, is turned by the force of water against the blades due to the forward motion of the ship. The speed of the propeller rotation is proportional to the speed of the ship. Therefore, the rpm of the propeller is proportional to the distance the ship travels per minute. In other words, for a ship traveling at 25 knots the propeller turns at 3,539 rpm. The relation between the rpm of the propeller and the speed of the ship is linear. The turning of the propeller generates an a-c voltage at a rate of 4 cycles per revolution of the propeller. Because each turn of the propeller represents a measured distance and each turn generates 4 cycles of voltage, each cycle is a measure of distance, and the frequency of the generated voltage is a measure of speed.

RODMETER AMPLIFIER.—The rodmeter amplifier consists of a voltage amplifier, power amplifier, and power supply enclosed within a ventilated, splashproof housing. This amplifier amplifies the output energy of the 2-phase rodmeter generator to obtain sufficient power to drive the 2-phase, variable-frequency, synchronous motor in the transmitter-indicator.

The voltage amplifier is mounted on one chassis and the power amplifier and power supply are mounted on another chassis to form two complete units. These chassis in turn are mounted on individual racks that are attached

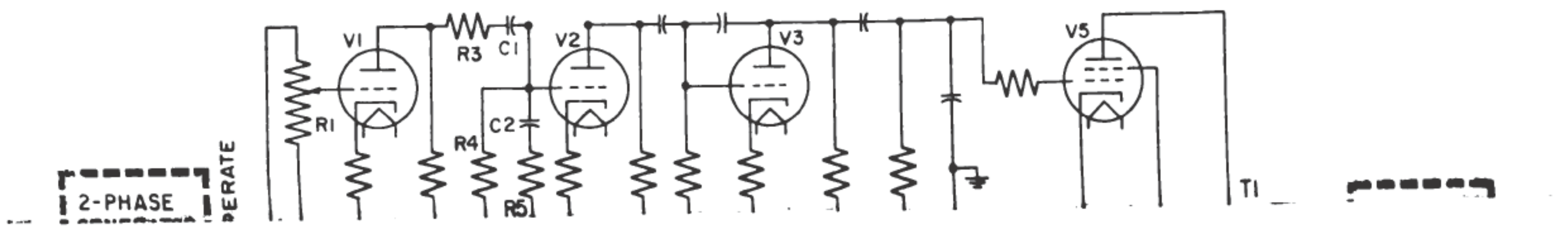
to the panel assembly. The front of each chassis is provided with a full-length piano hinge so that the unit can be opened and inverted to gain access to the internal components. The units are electrically connected to the panel assembly by means of male and female connectors to permit removal or replacement.

The panel assembly contains the transformers, chokes, capacitors, resistors, and other components necessary for the operation of the amplifiers, one for each phase, and the rectifier. The aluminum panel assembly is hinged to the housing so that it can be opened to expose the rear of the panel and also the terminal strips within the housing. When the panel assembly is open it can be removed by lifting it from the housing. Electrical connections are made from the panel to the terminal strips by means of a multiconductor cable.

A simplified schematic diagram of the rodmeter amplifier is shown in figure 4–30. For simplicity, the interference filters and the shielding are omitted. It consists of two similar amplifier circuits, one for each of the two phases, and two rectifier circuits to supply the d-c voltages for the plates and screens of these amplifiers. The gain controls, $R1$ and $R2$, are provided for each phase to adjust the output voltage to suit the requirements of the transmitter-indicator. The over-all gain is sufficient to permit normal operation with the gain controls at the mid-position.

The VOLTAGE AMPLIFIER circuit for phase 1 consists of $V1$ and $V2$ used as a straight voltage amplifier and $V3$ and $V4$ used as a phase inverter network to drive $V5$ and $V6$ in the power amplifier (V4 is the phase inverter triode). The RC attenuator circuit, consisting of $R3$, $C1$, $R4$, $C2$, and $R5$ between the first and second voltage amplifier stages, is used to adjust the over-all frequency response.

The inverse feedback used between a tertiary winding of output transformers $T1$ and $T2$ and the input grids of



2-PHASE
PERATE
V1
R1
R3
C1
V2
C2
R4
R5
V3
V5
T1

the third voltage amplifier stage stabilizes the power stages and absorbs any transients that might cause erratic operation of the unit.

The POWER AMPLIFIER circuit for phase 1 consists of $V5$ and $V6$ in push-pull class AB_1 amplification with essentially a fixed bias. Output transformer $T1$ for the power amplifier stage has an impedance ratio of 200:1. This ratio permits operation of $V5$ and $V6$ within their rated dissipation limits, while furnishing ample power at all frequencies between 9 and 225 cps to the variable-frequency motor in the transmitter-indicator.

The POWER SUPPLY consists of a low-current rectifier circuit and a high-current rectifier circuit.

The low-current circuit comprises a full-wave rectifier, $V13$. This supply is filtered by networks $L1C3$ and $L2C4$. The $B+$ voltage supplied by $V13$ and the secondary winding of $T3$ provide the necessary plate voltage for all the voltage-amplifier triodes and also grid bias for the power-amplifier beam-power tetrodes.

The high-current circuit consists of the full-wave rectifier twin diodes $V14$ and $V15$ with each tube acting as one-half of the rectifier circuit. The two plates of $V14$ are connected in series with equalizing resistors $R7$ and $R8$ and are paralleled to divide the load current. The two plates of $V15$ are similarly arranged. These resistors equalize the load current on each plate. The filaments of $V14$ and $V15$ are connected in parallel. This supply is filtered by $L3$ and $C5$. The high-current supply for the plates of the power-amplifier tubes is developed across $R11$ and $R12$. Resistor $R13$ provides grid circuit continuity between the fixed bias source and the plate and screen power supply for the power-amplifier tubes and tends to limit grid current in these tubes.

To provide a means of checking the amplifier against a standard, the 60-cycle controlled-frequency supply is fed into the amplifier through the step-down transformer, $T4$, and a DPDT switch, $S1$. The DPDT switch permits

either the 60-cycle, controlled-frequency supply or the output of the rodmeter to be fed into the input circuit of the amplifier.

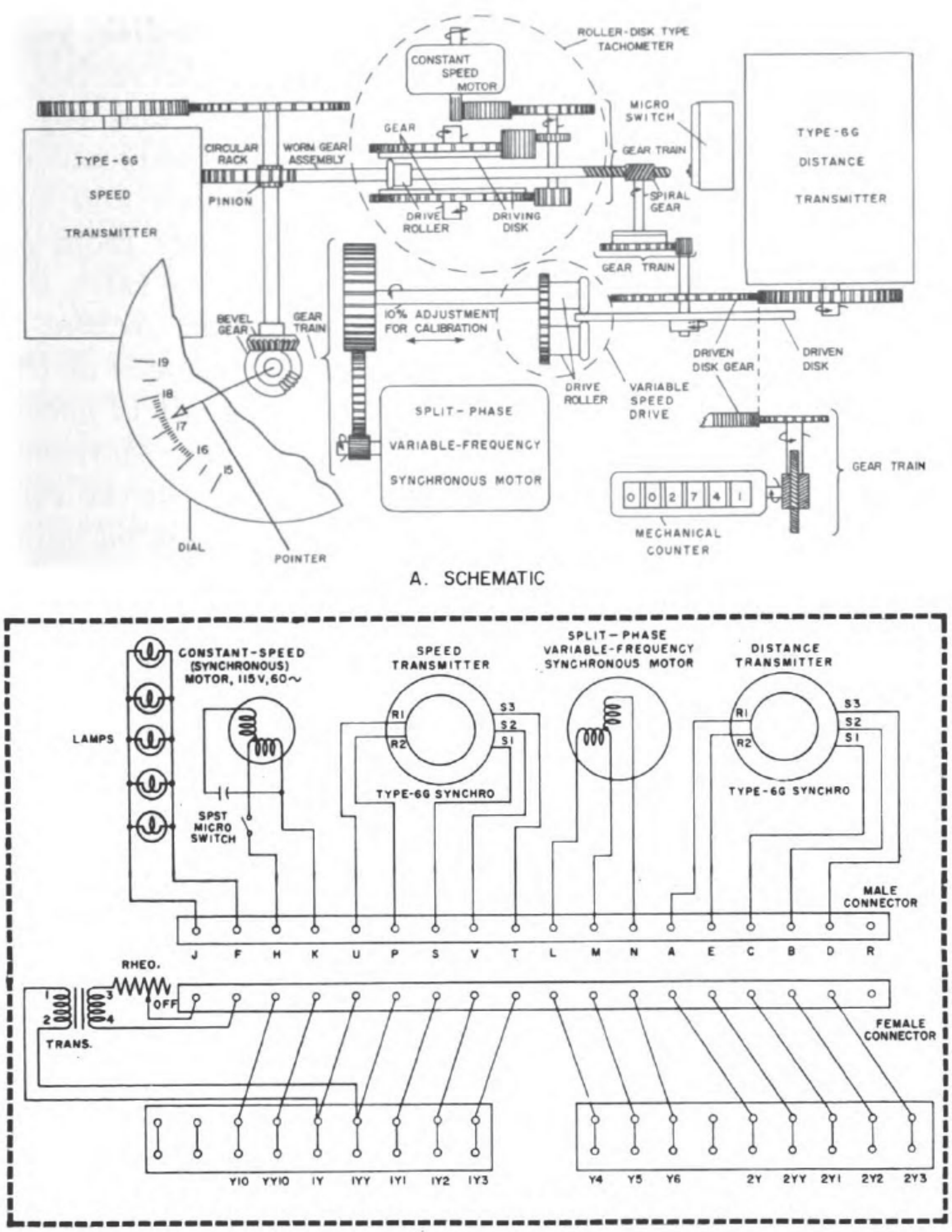
The rodmeter amplifier produces an output voltage such that the transmitter-indicator develops an approximately constant torque between 9 and 225 cps. At the lower end of the frequency range the waveform approximates a sine-wave pattern.

TRANSMITTER-INDICATOR. — The transmitter-indicator (fig. 4–31) consists of a mechanism assembly enclosed within a ventilated, splash-proof housing. The ship's speed is indicated by a pointer on a circular dial that is graduated from 0 to 25 knots. The distance traveled by the ship is registered on a digital-type revolution counter that indicates a maximum of 9,999.99 nautical miles.

The MECHANISM ASSEMBLY (fig. 4–31, A) consists essentially of a split-phase variable-frequency synchronous motor, the speed of which is proportional to the ship's speed; a revolution counter for registering the revolutions of this synchronous motor in terms of nautical miles; a type-6G synchro for transmitting the distance values; a roller-disk type of tachometer that measures and indicates (in terms of knots) the speed of the variable-frequency synchronous motor; and a type-6G synchro for transmitting the speed values. The entire mechanism is mounted on a common base plate to form a complete internal unit.

The split-phase variable-frequency synchronous motor receives voltage from the rodmeter amplifier. The frequency of the rodmeter amplifier output voltage determines the speed of the synchronous motor. Because this frequency is a measure of the ship's speed, the speed of the synchronous motor is a measure of speed. Likewise, because each cycle is a measure of the distance traveled by the ship, each revolution of the synchronous motor is a measure of distance.

The speed of the synchronous motor is measured by a roller-disk type of tachometer and is indicated as the ship's speed by a pointer on a circular dial. The syn-



B. CIRCUIT

Figure 4—31.—Transmitter-indicator of propeller type of underwater log system.

chronous motor is mechanically coupled to a revolution counter which indicates the distance traveled. A type-6G synchro, mechanically coupled to the speed indicating mechanism, transmits speed values in terms of knots, whereas a type-6G synchro, mechanically coupled to the synchronous motor, transmits distance values in terms of revolutions.

The synchronous motor drives the driven-disk gear through (1) a gear train; (2) an adjustable variable-speed drive consisting of two driving rollers; and (3) a driven disk. The roller-disk drive provides the means of altering the ratio between the driving rollers and the driven disk by moving the roller either away from or toward the center of the disk. By changing the ratio, the speed of the driven-disk gear can be changed so that it represents the speed of the ship and not the speed of the water passing the rodmeter. This adjustment is necessary because water-flow characteristics along different hulls vary somewhat and will cause the speed of the rodmeter propeller to vary slightly from the calculated value corresponding to a given ship's speed.

The motion of the driven-disk gear is transmitted through a gear train to a mechanical counter which counts the number of revolutions of the driven-disk gear, or the synchronous motor in terms of nautical miles, thereby indicating the distance traveled. The motion of the driven-disk gear is also transmitted to a type-6G synchro, each revolution of which represents the distance traveled—that is, 360 revolutions represents approximately 1 nautical mile.

The speed of the driven-disk gear, which is proportional to the speed of the ship, is converted into indications of ship's speed by means of the roller-disk type of tachometer. Motion of the driven-disk gear is transmitted by a gear train to the spiral gear which engages the worm gear assembly. The action of the spiral gear against the worm is that of a pinion on a rack, driving the roller linearly away from the center of the disks. However, the roller and its integral worm and circular rack are rotated by the two disks which are driven at a constant speed by a constant-frequency synchronous motor through a gear train.

The speed of the circular motion of the roller depends upon its position with respect to the center of the two disks, increasing as the roller moves toward the edge of

the disks and decreasing as it moves toward the center. Hence, the roller receives circular and linear motion simultaneously. Although the driving action of the spiral gear against the worm tends to drive the roller away from the center of the disks, the motion resulting from the revolving of the worm engaging the spiral gear is toward the center of the disks.

When the circular motion and the linear motion balance each other, the roller will assume a position of displacement away from the center of the disks proportional to the speed of the spiral gear. Because the speed of the spiral gear is proportional to the frequency of the voltage generated by the rodmeter unit, the displacement of the roller is proportional to the speed of the ship. The roller, which is attached to the gear assembly, positions the gear-assembly shaft linearly in proportion to the speed of the ship. The circular rack of the gear assembly engages a pinion and transforms linear motion into proportional circular motion through the two bevel gears. This circular motion is transmitted to a pointer that indicates the ship's speed in knots on a circular dial.

Illumination is provided by three lamps for the dial and two lamps for the counter register. Light diffuser plates attached to the inside of the cover collect the light rays from the lamps and distribute the light evenly over the dial and counter register. A transformer inside the housing supplies the dial-lamp circuit and a variable resistor in series with this circuit controls the intensity of illumination.

The wiring diagram for this instrument is shown in figure 4–31, B.

SHIP CONTROL CONSOLES

Ship control consoles are installed in some recent naval vessels. These consoles concentrate in one location many of the controls, indicators, and communications instruments formerly scattered in several locations about the

bridge. These instruments are combined in one cabinet, which usually weighs less and requires less space than the same instruments installed separately. The components of the console are mounted so that they are easily visible and accessible to the personnel concerned with the control of the ship.

Pilot House Console

The pilot house console (fig. 4–32) consists of a right-hand section and a left-hand section. The right-hand section contains the instruments and controls associated with steering, such as the helm and its synchro transmitter; gyrocompass repeaters; magnesyn compass indicator, steering order and rudder transmitter and rudder angle indicator; course-steering order indicator; steering control cable selector switch; steering emergency alarm switch; and press-to-cutout damping switch for the gyrocompass.

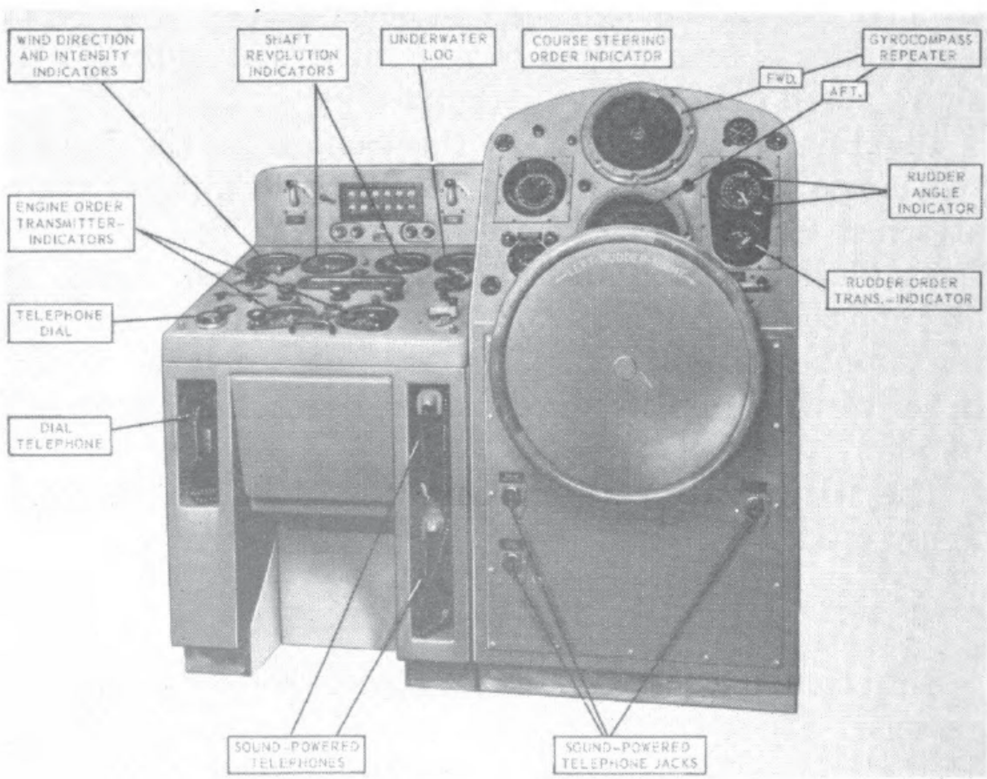


Figure 4—32.—Pilot house console.

The left-hand section contains the instruments and controls associated with engine control, communications, and various metering and indicating instruments. These include the engine order transmitter-indicator; propeller order transmitter-indicators; shaft revolution indicators; wind direction and intensity indicators; underwater log indicator; general and chemical alarm switches; whistle switch; speed-light control; truck selector switches; sound-powered telephone selector switches; sound-powered telephone annunciator drops; backing indicator lights; and dial telephone and sound-powered telephone handsets.

Both sections are equipped with the necessary dial lights for each instrument, and individual dimmer rheostats are provided as necessary. Indicator lights, where installed, are equipped with mechanical shutters for reducing the light intensity.

The OPEN BRIDGE CONSOLE is designed for bulkhead mounting. It contains the engine order transmitter-indicator; rudder order transmitter; rudder angle indicator; and gyrocompass repeater.

Communications Console

The communications console (fig. 4–33) is installed in the combat information center (CIC) and tactical plot. This console provides a convenient grouping in one location of a large number of sound-powered telephone circuits, radio circuits, and ship's intercommunications stations. The communications console provides a means of: (1) monitoring or transmitting on various radio circuits available at the console; (2) monitoring or transmitting over the many sound-powered telephone circuits as provided with the console; (3) controlling the selection of radio channels to external talkers located in the combat information center; (4) selecting any of the radio circuits for monitoring and playback from a short-memory voice recorder; and (5) controlling a maximum of 30 ship's intercommunications stations.

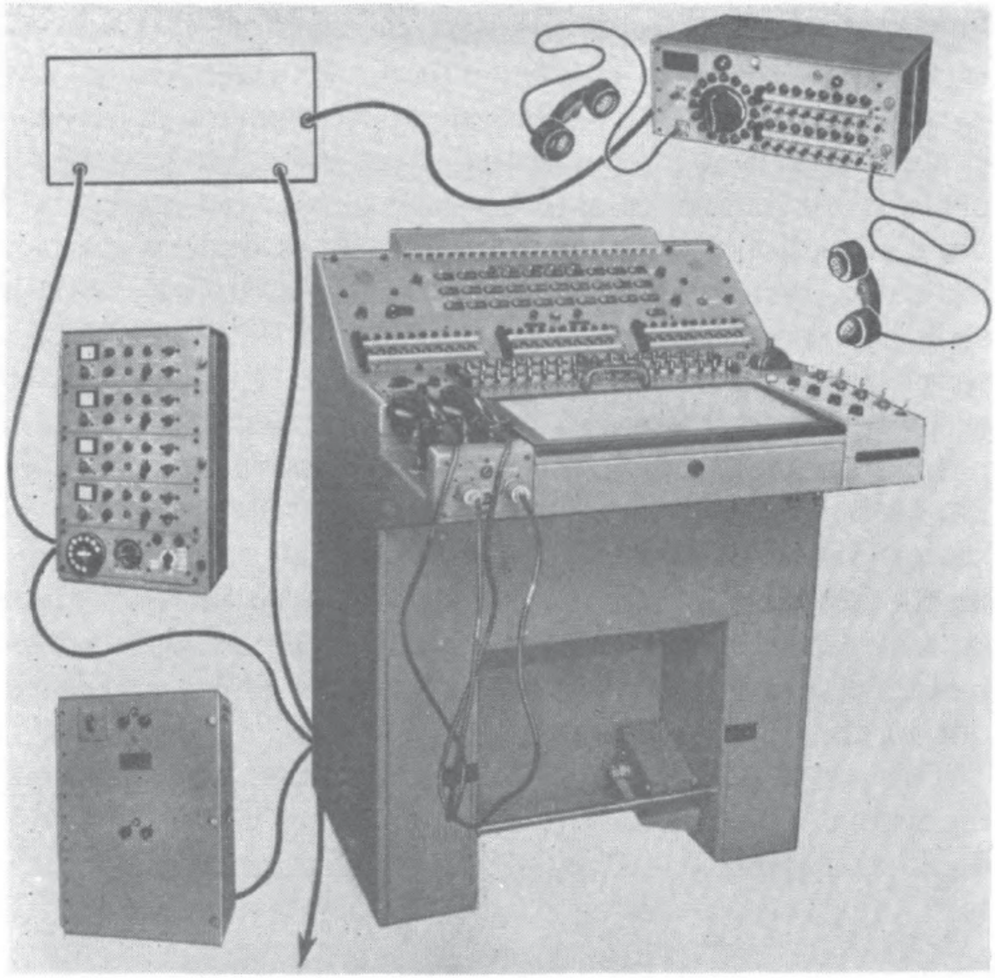


Figure 4—33.—Communications console.

The covers of the control consoles can be removed and all instruments easily withdrawn for service as a complete unit because these instruments are equipped with plug-type connectors.

QUIZ

1. Name the three functions of the shaft revolution indicator system, circuit K.
2. What is the function of the shaft transmitters?
3. What is the function of the master transmitter-indicators in the shaft revolution indicator system?
4. What is the function of the indicators in the shaft revolution indicator system?

5. What is the purpose of the unidirectional mechanism?
6. Name the three principal components that comprise the master transmitter-indicator of the type-A shaft revolution indicator system.
7. What is the function of the type-5G positioning synchro in the master transmitter-indicator?
8. Name the two principal components of a magneto-voltmeter type shaft revolution indicator system.
9. What are the functions of the two principal components of a magneto-voltmeter type of shaft revolution indicator system?
10. What are the four principal components of the magneto-type transmitter?
11. How is uniform polarity of the magneto transmitter output maintained, irrespective of the direction in which the transmitter is driven?
12. What are the four principal components of the indicator of a magneto-voltmeter type shaft revolution indicator system?
13. How is the shaft rpm indicated by the indicator of a magneto-voltmeter type of shaft revolution indicator system?
14. What are the two purposes of the wind direction and intensity indicator system?
15. (a) Name the two principal components that comprise the foremast transmitter of a wind direction and intensity indicator system. (b) Where are these components located within the transmitter housing?
16. What is the purpose of the master wind direction and intensity transmitter?
17. On what principle is the operation of the salinity indicator system based?
18. What type of meter is used in the indicator circuit of a salinity indicator system?
19. (a) What load is connected in series with each of the movable coils of the meter in the salinity indicator circuit? (b) What ratio determines the meter reading? (c) What is the function of the compensator in the indicator circuit? (d) How is the output voltage of the bridge alarm circuit connected with respect to the thyratron bias voltage? (e) What is the effect of excessive salinity in the cell upon the thyratron control grid voltage and tube conduction?

20. What is the purpose of the underwater log system?
21. Name the two general types of underwater log equipments installed in naval vessels.
22. Name the four principal components that comprise the hydraulic type of underwater log system.
23. Where is the rodmeter located with respect to the keel of the ship and its turning point?
24. What are the specific locations of the dynamic and static orifices on the rodmeter?
25. What relative pressure is exerted on the static and dynamic orifices when the rodmeter is in the operating position and the ship is stationary?
26. How is the differential pressure related to the pressures at the dynamic orifice and the static orifices?
27. To what device is the pressure from the (a) dynamic orifice transmitted, and from the (b) static orifices transmitted?
28. Name the three principal components of the rotary distance transmitter of the hydraulic underwater log system.
29. (a) To what device is the rotary motion transmitted from the 60 revolutions per mile transmitter, and (b) from the 360 revolutions per nautical mile transmitter?
30. What is the function of the master speed indicator in the hydraulic underwater log system?
31. What is the function of the speed and distance indicator in the hydraulic underwater log system?
32. Name the three principal components that comprise the propeller type of underwater log system.
33. What is the purpose of the rodmeter amplifier in the propeller type of underwater log system?
34. What is the purpose of ship control consoles?
35. What is the advantage of communications consoles?

CHAPTER 5

PRINCIPLES OF MAGNETIC AMPLIFIERS

INTRODUCTION

The amplification of voltage or power is usually associated with electron tubes. However, this amplification can be accomplished by means of other devices, such as the magnetic amplifier and the transistor.

The magnetic amplifier employs as the controllable element an iron-cored inductance. The magnitude of this inductance is a function of the control current. By varying the control current a small amount, the power delivered to a load is varied through a much wider range.

The magnetic amplifier described in this chapter has certain advantages over electron tube amplifiers. These include (1) high efficiency (90+%), (2) reliability (long life, freedom from maintenance, reduction of spare parts inventory), (3) ruggedness (shock and vibration resistance, overload capability, freedom from effects of moisture), (4) space and weight economy, and (5) no warm-up time. The magnetic amplifier has no moving parts and thus can be hermetically sealed within a case similar to the conventional dry-type transformer. The magnetic amplifier has a few disadvantages. For example, it cannot handle low-level signals; it is not useful at high frequencies; it has a time delay caused by its

modulated carrier system; and the output waveform is not an exact reproduction of the input waveform.

The magnetic amplifier is important to many phases of naval engineering because it provides a rugged, trouble-free device that has many applications aboard ship. These applications include throttle controls on the main engines, speed, frequency, voltage, current, and temperature controls on auxiliary equipment; fire control, servomechanisms, and stabilizers for guns, radar, and sonar equipment; and pulse-forming sweep multivibrator circuits for radar and loran equipment.

The evolution of a practical magnetic amplifier has resulted from the recent development of high-quality steels, gapless construction of the magnetic circuit, special low-leakage rectifiers, and self-saturating magnetic circuits. The improvement in processing magnetic materials and the successful development of dry-disk or metallic rectifiers have contributed principally to the wide use of this device as an amplifier. High-quality steels have increased the power handling capacity. The dry-disk rectifiers convert either the entire output or part of the output from alternating current to direct current. Variations in the control current level, like the variations in grid voltage of a thyratron, produce corresponding variations in the output.

Early Types Of Saturable Cores

Early saturable reactors employed ordinary transformer silicon-steel cores. The amplifying qualities of these devices were not very satisfactory because of the relatively low saturation flux density and high hysteresis loss.

Materials Suitable For Magnetic Amplifier Cores

Various types of nickel-iron alloys that have more suitable magnetic properties for use as core materials for saturable reactors have been developed and are com-

mercially available. These materials are the (1) high-permeability alloys and (2) grain-oriented alloys.

The high-permeability materials include Permalloy *A*, Mumetal, and 1040 alloy, which have high values of saturation flux density and relatively narrow and steep hysteresis loops. These materials are used extensively as the cores in low-level input amplifier stages.

The grain-oriented materials include Orthonol, Deltamax, and Permenorm 5000–*Z* alloy, which have even higher values of saturation flux density and more rectangular-shaped hysteresis loops (fig. 5–1, A) than the high permeability materials. Grain-oriented materials are referred to as square-loop materials because of the flat top and bottom of the hysteresis loop. (A conventional loop is shown in figure 5–1, B) These materials are used as the cores in high-level output amplifier stages in which maximum permeability occurs close to saturation flux density, resulting in a substantial increase in the power-handling capacity for a given weight of core material.

In the manufacture of saturable cores, the character-

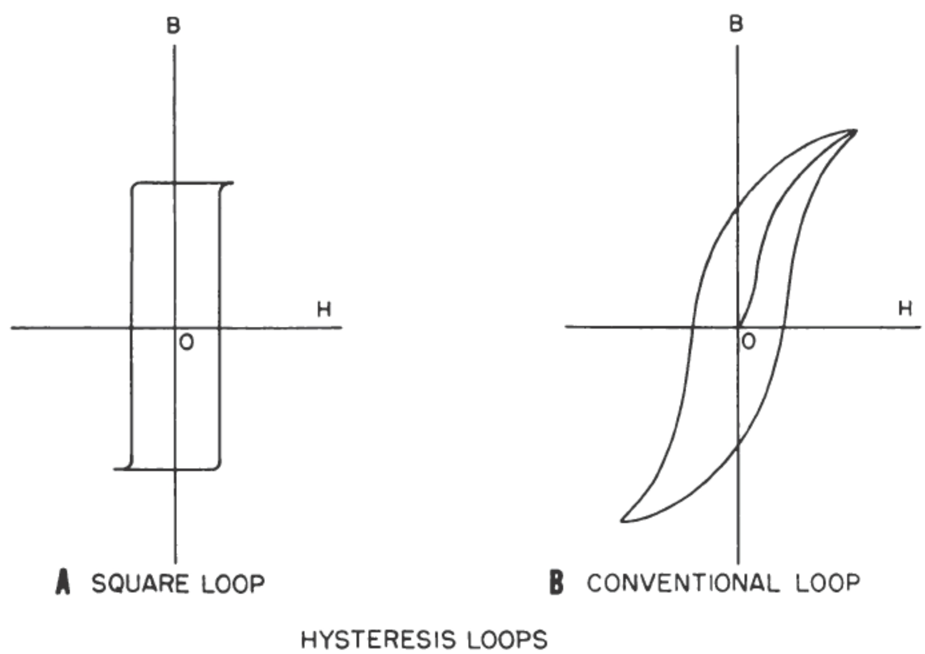


Figure 5—1.—Hysteresis loops.

istics of the grain structure of the material can be altered considerably by rolling and annealing processes.

A great improvement in the magnetic properties of some materials is obtained by cold rolling the material before it is annealed. The cold-rolling process develops an orientation of the grain in the direction of rolling. If a magnetizing force is applied to the material so that the flux is in the direction of the grains, a rectangular hysteresis loop is obtained. Thus, in some materials cold rolling produces almost infinite permeability up to the knee and almost complete saturation beyond the knee.

BASIC HALF-WAVE CIRCUIT

In order to demonstrate the operating principles of magnetic amplifiers in general, a description of a simple half-wave circuit (fig. 5–2, A) will be given.

Windings

This magnetic amplifier circuit contains a magnetic core made of a square loop material, upon which two windings are placed. The load or "gating" winding is connected in series with a rectifier, the load, and an a-c power supply. A second or "control" winding is connected in series with a rectifier, the control signal, and the same a-c source. The two windings have a 1:1 turns ratio. The magnetic amplifier acts in this circuit like a thyratron tube that gates (turns on) the load circuit periodically. A control voltage applied to the thyratron grid determines the point of ionization of the tube on the positive half cycles of plate voltage, and pulses of load current flow through the tube. On alternate half cycles when the plate voltage is negative with respect to the cathode, the tube deionizes and load current ceases.

The action of the control winding of the magnetic amplifier may be compared to that of the thyratron grid. The action of the load winding may be compared to that of the thyratron cathode-plate circuit. The action is that of introducing a high impedance for a controlled portion of

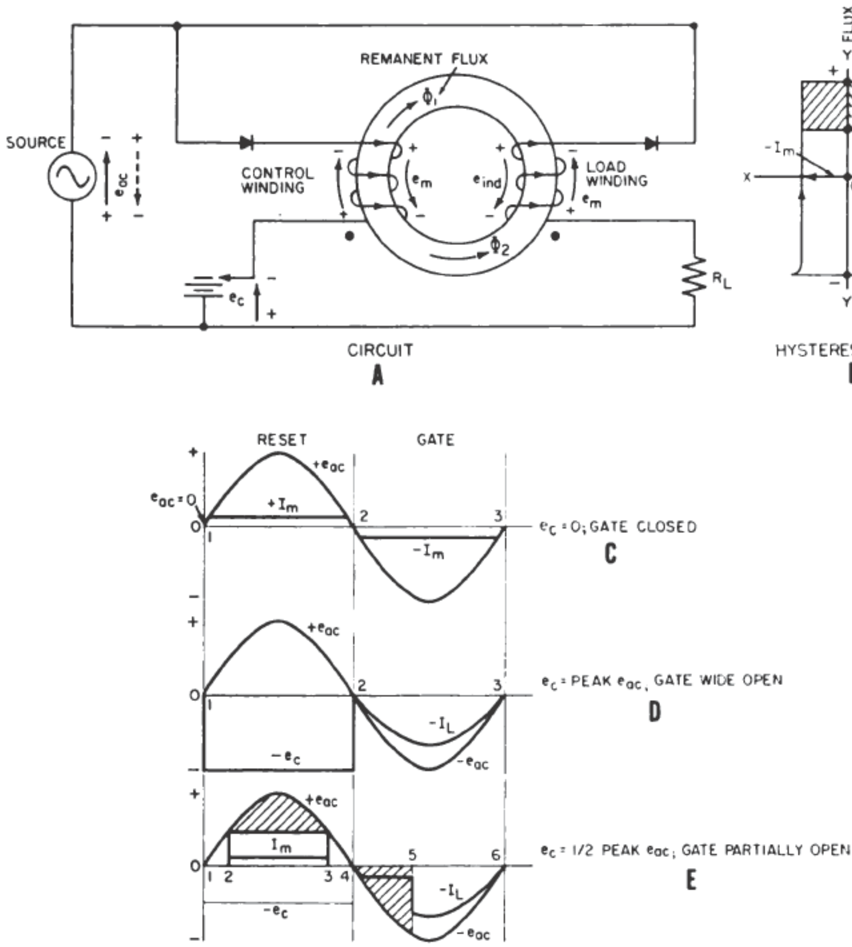


Figure 5—2.—Basic half-wave magnetic amplifier.

each half cycle and then removing this impedance and allowing load current to flow during the remaining portion of the half cycle. During the following half cycle the magnetization is "reset" or changed to another operating point on the hysteresis loop.

Polarities

The solid arrow at the source (fig. 5–2, A) indicates the direction of electron flow through the circuit during the positive half cycles of applied voltage, e_{ac}. By convention, current flow is opposite to electron flow. The polarity markings (dots at one end of the windings) are indicative of the way the turns are wound on the core. The dotted ends of the windings of a core are assumed to

always have a particular instantaneous polarity with respect to the undotted ends of the windings. Also the dotted ends of two or more windings on a common core are considered to have the same instantaneous polarity with respect to each other. For example, in figure 5–2, A, if the voltage applied to the control winding is of a polarity to cause current to flow INTO the dot-marked end of that winding, the induced voltage of the other winding will be of a polarity such as to cause current to flow OUT OF the dot-marked end of that winding. The control voltage, e_c, is assumed to be a direct voltage. The rectifier arrowheads are pointed in the direction of electron flow to help maintain the analogy to thyratron operation. This direction is opposite to conventional commercial usage.

Function Of The Rectifiers

Rectifiers are placed in the load and control circuits to prohibit current flow in both the control circuit during the gating half cycle and in the load or gating circuit during the reset half cycle. The magnetic amplifier is not an amplifier in the sense of a stepup transformer. Voltages generated by mutual induction (transformer action) between the control and load windings do exist in these windings but they have only a small effect on the amplifier operation under the established conditions.

During the first half cycle of the applied voltage, the direction of the INDUCED voltages in both windings is INTO, or positive at the polarity-marked terminals. In the load winding this action is in the forward direction of the rectifier and against e_{ac}. Thus, the rectifier in the load circuit prevents current flow through the load and is subjected to an inverse voltage equal to the difference between e_{ac} and the mutually induced voltage in the load winding. The time interval, corresponding to the first half cycle, is called the "reset" half cycle.

Analysis With Zero D-C Control Voltage

As mentioned previously, figure 5–2 is used in the analysis of the action of the basic half-wave magnetic ampli-

fier. Figure 5–2, A, represents the basic circuit. Figure 5–2, B, represents the square-type hysteresis loop for the core material used in this circuit. Figure 5–2, C, D, and E, represents the waveforms of current and voltage for three conditions to be considered. The symbol representing a quantity is common to all parts of the figure. For example, the magnetizing current, I_m, is represented in figure 5–2, B, C, and E. The hysteresis loop is enlarged for clarity and is not drawn to the same scale as parts C, D, and E.

RESET HALF-CYCLE.—The FIRST condition to be described is with the control voltage, e_c, at zero. At the beginning of the reset half-cycle, the core is assumed to possess a residual, or positive saturation remanent flux level, ϕ_1 (fig. 5–2, B). The direction of this flux is indicated as ϕ_1 in figure 5–2, A. As e_{ac} increases from zero in a positive direction (indicated by the solid arrow at the source, fig. 5–2, A) and by the part of the sine curve, point 1 to point 2 (fig. 5–2, C), the current in the control winding establishes an mmf represented by half the width of the hysteresis loop, $+I_m$ (fig. 5–2, B). The applied voltage establishes an mmf that acts in a direction to oppose the residual core flux, ϕ_1, and therefore to demagnetize the core. The amount of change of flux will depend upon the MAGNITUDE of the applied voltage across the control winding and the TIME INTERVAL during which this voltage is applied.

In this example, the first half-cycle of applied voltage is assumed to reverse the core magnetism and to establish its flux density at essentially the negative saturation remanent level ϕ_2 (fig. 5–2, B).

As e_{ac} increases from zero in a positive direction in the vicinity of point 1 (fig. 5–2, C), there is no change in core flux until the current increases to the value of $+I_m$, corresponding to one-half of the width of the hysteresis loop. Thus, with no flux change, the current rises abruptly and is limited only by the resistance of the circuit and the low

value of e_{ac}. When the current reaches the value, $+I_m$, the core flux starts to change from the ϕ_1 level toward the ϕ_2 level (fig. 5–2, B). The accompanying self-induced voltage opposes e_{ac} and limits the current to a constant small value, $+I_m$, during the flux excursion from the level ϕ_1 to ϕ_2.

This flux change continues during the time interval between point 1 and point 2 (fig. 5–2, C). As it continues, the induced voltage continues to vary in magnitude with e_{ac} and to oppose e_{ac} in such a manner that $+I_m$ remains constant over the half-cycle interval.

GATING HALF-CYCLE.—The next half-cycle is called the "gating" half-cycle. It starts at point 2 (fig. 5–2, C), at which time the polarity of the applied voltage reverses. The direction of e_{ac} for this half-cycle is indicated by the dotted arrow (fig. 5–2, A). During this time interval, the rectifier in the control circuit blocks the flow of control circuit current. However, the rectifier in the load circuit permits current from the source to flow in that circuit. This current will magnetize the core in a positive direction—that is, in a direction to change the flux from the ϕ_2 level to the ϕ_1 level. The applied voltage is assumed to be of the correct magnitude to cause the core to be magnetized to the ϕ_1 level (fig. 5–2, B). A condition of equilibrium is indicated.

The large flux change from the ϕ_2 level to the ϕ_1 level causes a self-induced voltage in the load winding and a mutually induced voltage in the control winding. The self-induced voltage in the load winding opposes e_{ac}. The mutually induced voltage in the control winding also opposes e_{ac}. The rectifier in the control winding circuit is subjected to an inverse voltage equal to the difference between e_{ac} and the mutually induced voltage in the control winding. Because of the maximum flux change in the core, maximum impedance is presented by the load winding to the circuit containing R_L throughout the gating half cycle, and therefore e_{ac} will appear across the load

winding and not across R_L. For this condition the current through the load is limited to a very small magnetizing component that is negligible compared to normal values of load current. The gate is closed. The action is analogous to that of a thyratron tube with its grid biased beyond cutoff.

Analysis With Maximum D-c Control Voltage

The SECOND condition described is for the condition that e_c is equal to the peak value of e_{ac}. At point 1 (fig. 5–2, D), the remanent magnetism is again at the ϕ_1 level (fig. 5–2, B).

FIRST HALF CYCLE.—The applied voltage, e_{ac}, rises from zero to maximum during the first 90° of the cycle, but has no effect on the core flux because the control voltage, e_c, has a magnitude equal to the maximum value of e_{ac}, and a polarity opposite to that of e_{ac}. The direction of e_c is against the rectifier in the control circuit. Thus, the rectifier prevents the flow of battery control current during the time that e_c is greater than e_{ac}. Because there is no voltage across the control winding (the rectifier is essentially an open circuit), no flux change can occur from point 1 to point 2 (fig. 5–2, D). Figure 5–2, B does not apply. Thus, no change in flux occurs during the reset half cycle for this assumed condition.

SECOND HALF CYCLE.—When e_{ac} reverses its polarity (solid to dotted arrow), the rectifier in the control circuit continues to block the flow of current in that circuit. In the load circuit, the polarity of e_{ac}, during the gating interval, points 2 to 3 (fig. 5–2, D), is such as to tend to drive the core further into positive saturation, point 1*a* (fig. 5–2, B). Because the core is already saturated, no further flux change occurs, and e_{ac} appears across R_L because the load winding offers no impedance to I_L.

The full value of load current flows, and its magnitude is $\frac{e_{ac}}{R_L}$ The gate is wide open. The condition is analo-

gous to a thyratron tube that has no grid bias. The tube fires when the plate is only slightly positive, and conduction occurs immediately and continues for essentially the full half cycle. The waveform of this current is indicated in figure 5–2, D.

Analysis With Partial D-c Control Voltage

The THIRD condition assumes that e_c is approximately half the peak value of e_{ac}. During the reset half cycle, voltage is applied to the control winding during the time interval from point 2 to point 3 (fig. 5–2, E). The magnitude of this voltage is $e_{ac} - e_c$. This voltage will be less than the peak value of e_{ac}, but greater than zero; and a new set of conditions will be established.

FIRST HALF CYCLE.—The starting point is again on the ϕ_1 level (fig. 5–2, B). The reset cycle is just beginning. During the interval, 1 to 2 (fig. 5–2, E), e_c is greater than e_{ac}, and the rectifier opposes any current flow in the control winding. During the interval, 2 to 3, e_{ac} exceeds e_c, and magnetizing current flows in the control winding. As mentioned previously, the extent of the change in core flux will depend on the time interval and magnitude of the voltage applied across the control winding within the half cycle. Because the time interval is very short and the net voltage applied to the control winding is much less than e_{ac}, the core flux level is assumed to change from ϕ_1 to the level along the line through ϕ_3 (fig. 5–2, B). During the interval, 3 to 4 (fig. 5–2, E), e_{ac} is again less than e_c, and the rectifier prevents any further flow of control current. As in the previous examples, the rectifier in the load circuit prevents any current flow in that circuit during the reset half cycle.

SECOND HALF CYCLE.—When e_{ac} reverses, magnetizing current flowing through the load winding changes the core flux from the level through point 3 to the level through point 1 (fig. 5–2, B). This change is assumed to take place during the interval, 4 to 5 (fig. 5–2, E). The impedance of the load winding is high during this interval,

and current flow through the load is restricted to the magnetizing current. However, at point 5 the core becomes saturated and no further flux change occurs. The impedance of the core drops to zero and current, $\frac{e_{ac}}{R_L}$, flows through the load during the interval from 5 to 6. The load voltage is in phase with e_{ac} and has the same waveform as that of e_{ac} for this part of the cycle.

Energy Considerations

The area of the portion of the hysteresis loop traversed is a measure of the energy required to complete that particular cycle of magnetization. It may be divided equally by the y-axis. For condition 1 (fig. 5–2, C), the entire right-hand area of the loop shown in figure 5–2, B is proportional to the area under the $+e_{ac}$ voltage wave (which is proportional to the energy supplied), and the left-hand area is proportional to the area under the $-e_{ac}$ voltage wave. For condition 2 (fig. 5–2, D), the area (in both) is zero (no flux change occurred), and the load, R_L, absorbs the entire applied voltage, e_{ac}. No energy is supplied to the control winding. For condition 3 (fig. 5–2, E), the right-hand shaded area of the hysteresis loop (fig. 5–2, B) is proportional to the shaded area under $+e_{ac}$ (fig. 5–2, E), and the left-hand shaded area of the hysteresis loop is proportional to the shaded area of $-e_{ac}$. In this case, the magnitude of $(e_{ac} - e_c)$ applied to the control winding determines how far the core flux is carried from positive saturation toward negative saturation, and consequently how much of the gating half cycle that will be nonconducting.

For condition 3, the energy supplied to the control winding is partially reduced. The corresponding area is reduced from the total area under $+e_{ac}$ for condition 1 to that indicated by the shaded portion under the $+e_{ac}$ curve in figure 5–2, E. The flux change is not carried to level ϕ_2 on the hysteresis loop but to some point part way down

the loop (level ϕ_3) as determined by the shaded area under the $+e_{ac}$ curve.

In other words, the time in the gating half cycle at which the core saturates (the firing angle) is determined by the shaded area under the $+e_{ac}$ curve or the amount of energy supplied to the control winding during the reset half cycle. Thus, as e_c is reduced in magnitude, the voltage, $e_{ac} - e_c$, applied to the control winding increases, and the core flux is carried further toward negative saturation during the reset half cycle.

This action increases the firing angle and delays the time in the gating half cycle when the core saturates and the load winding becomes conducting. Thus, the average load current and load voltages are reduced. They both vary directly with the control voltage.

FULL-WAVE BRIDGE CIRCUIT

The basic circuits and waveforms for a full-wave bridge magnetic amplifier are illustrated in figure 5–3.

NOTE: Figure 5–3 is a fold-in. For ease in following the analysis of figure 5–3, as developed in the text, the figure is placed at the end of the chapter.

The core material is assumed to have the same characteristics as those of the rectangular hysteresis loop core employed in the half-wave circuits. The analysis is done in color in order to identify more readily the simultaneous actions occurring in different parts of the figure. Figure 5–3, A and B, represents the same magnetic amplifier. The circuits are repeated in order to identify the actions for each half cycle of applied voltage. Thus, the red and yellow circuits in Figure 5–3, A, represent the active (conducting) circuits for the first half cycle, and the blue and green circuits of figure 5–3, B, represent the active circuits for the second half cycle. The applied voltage, e_{ac}, appears twice in each figure for purposes of simplification; actually e_{ac} originates at only one source. This source is common to all inputs across which e_{ac} appears.

Figure 5–3, C, D, and E, represents the waveforms of applied voltage and current for the windings of the magnetic amplifier for three separate conditions of control voltage, e_c. For example, e_{ac} activating the control circuit in figure 5–3, A (yellow) is illustrated by the yellow waveform of figure 5–3, C, D, or E; the resulting core flux change is shown as the yellow portion of the hysteresis loop in figure 5–3, F.

Simultaneously, e_{ac} activating the load winding (red) is illustrated by the red waveforms in figure 5–3, C, D, or E; the resultant core flux change is shown by the red portion of figure 5–3, F. Similarly, on the second half cycle the simultaneous actions occurring in the blue and green windings correspond to the blue and green waveforms of voltage and current in figure 5–3, C, D, or E; the corresponding flux changes are shown in the blue and green portions of the hysteresis loop (fig. 5–3, F).

In the step-by-step analysis the same three conditions that were considered in the half-wave circuit will now be considered: (1) $e_c = 0$ (fig. 5–3, C), (2) $e_c = e_{ac}$ peak (fig. 5–3, D), and (3) $e_c = \frac{1}{2}\, e_{ac}$ peak (fig. 5–3, E). It is assumed that when e_{ac} is zero, points 1 (fig. 5–3, C), the remanent flux of core ① (yellow) will be at level 1, and of core ② (red) will be at level 2 (fig. 5–3, F).

Analysis with e_c Equal to Zero

When $e_c = 0$, the two circuits that are active for the first half cycle of e_{ac} are shown in yellow (control) and red (load) of figure 5–3, A. The two circuits that are active for the second half cycle are shown in the blue (control) and green (load) of figure 5–3, B.

POLARITIES.—The applied voltage, e_{ac} (yellow) is considered to be positive when the direction is OUT on the polarity-marked end of the control winding of core ①. It will be negative for core ② since the direction is IN on the polarity-marked end of the load winding of core ②. Obviously the waveforms of the source voltage cannot be both positive and negative at the same instant with re-

spect to their direction through the SAME windings or through the common source. It should be noted that the waveforms of e_{ac} are positive with respect to one winding and negative with respect to another winding, only because of the manner in which e_{ac} is applied to the winding.

FIRST HALF CYCLE.—As e_{ac} increases from zero in the first half cycle (fig. 5–3, C, yellow and red), the direction of e_{ac} is against the rectifier in series with the control winding of core ② and with the rectifier in series with the control winding of core ①. Therefore, NO current flows in the control winding of core ②, and a current will flow in the control winding of core ①. The magnitude of the current flowing in the control winding is assumed to be proportional to half the width of the hysteresis loop for core ①. The extent of the flux change depends on the magnitude of e_{ac}; and for the case, $e_c = 0$, the current flowing in the control winding of core ① is assumed to change the level of flux from positive saturation remanence at point 1 to negative saturation remanence at point 2 (fig. 5–3, F, yellow). This action is said to RESET the flux in core ①, and this portion of the cycle is said to be the RESET half cycle for core ①.

During the same half cycle, the direction of e_{ac} is against the rectifier in series with the load winding of core ① and with the rectifier in series with the load winding (red) of core ②. Therefore, no current flows in the load winding of core ① and current will flow in the load winding of core ②. The path for load current includes the a-c supply and the load, R_L. The magnitude of e_{ac} is of such a value that the current flowing through R_L and the load winding of core ② is limited to the magnetizing current, $-I_m$. The magnitude of I_m is proportional to one half the width of the hysteresis loop, and during this half cycle the flux of core ② is changed from negative saturation remanence at level 2 (fig. 5–3, F, red) to positive saturation remanence at level 1. This half cycle is called the GATING half cycle for core ②. Because the flux change is a maximum, the

impedance developed by the load winding of core ② is a maximum, and e_{ac} appears across this load winding. The load voltage and the load component of current are zero. This condition corresponds to the condition when e_c is equal to zero.

To summarize the action in the two cores during the first half cycle of e_{ac}:

1. Current flows through the control winding of core ① and resets the flux of core ① from level 1 to level 2 (fig. 5–3, F, yellow).
2. Magnetizing current flows through the load winding of core ② during the gating half cycle for core ②, and the flux changes from level 2 to level 1 (fig. 5–3, F, red).
3. The rectifiers prevent the flow of current through the control winding of core ② and the load winding of core ①.
4. The flux change during the gating half cycle of core ② is a maximum; therefore, the impedance is a maximum and the load component of current through R_L is zero.

SECOND HALF CYCLE.—During the second half cycle of e_{ac}, points 2 to points 3 (fig. 5–3, C), the polarity of e_{ac} will reverse. As mentioned previously, the polarities of e_{ac} for the second half cycle are indicated in figure 5–3, B, and the paths for current flow are represented in blue for the control winding of core ② and in green for the load winding of core ①.

As e_{ac} increases from zero with reversed polarity at points 2 (fig. 5–3, C), the direction of e_{ac} is against the rectifier in the control winding of core ① (fig. 5–3, B) and with the rectifier in the control winding (blue) of core ②. Therefore, no current will flow in the control winding of core ①, and current will flow in the control winding of core ②. The cores are assumed to be identical; and for the condition, $e_c = 0$, the magnitude of the current flow-

ing in the control winding of core ② will be proportional to half the width of the hysteresis loop for core ②. The current flowing in the control winding of core ② is assumed to change the level of the flux in core ② from positive saturation remanence at level 1 (fig. 5–3, F, blue) to negative saturation remanence at level 2. This time interval is the reset half cycle for core ②.

During this same interval of time (the second half cycle of e_{ac}), the direction of e_{ac} is against the rectifier in series with the load winding of core ② (fig. 5–3, B) and with the rectifier in series with the load winding (green) of core ①. Therefore, no current will flow in the load winding of core ②, and current will flow in the load winding of core ①. The latter path includes the a-c supply and the load, R_L. The direction of flow through the a-c supply is opposite to that for the first half cycle, but the direction through R_L is the same as it was during the first half cycle because of the arrangement of the rectifiers. As in the first half cycle, the magnitude of current flowing through the load winding of core ① is limited to the magnetizing current, $-I_m$. The magnitude of I_m is proportional to one half the width of the hysteresis loop. During the second half cycle, the flux of core ① is changed from negative saturation remanence at level 2 (fig. 5–3, F, green) to positive saturation remanence at point 1. This half cycle is the gating half cycle for core ①. Because the flux change is a maximum, the impedance developed by the load winding of core ① is a maximum, and e_{ac} appears across this load winding. The load voltage and the load component of current are zero. As mentioned before, this condition corresponds to $e_c = 0$.

To summarize the action in the two cores during the second half cycle:

1. Current flows through the control winding (blue) of core ② (fig. 5–3, B) and resets the flux of core ② from level 1 to level 2 (fig. 5–3, F).
2. Magnetizing current flows through the load winding

of core ① (green) during the gating half cycle for core ①, and the flux changes in core ① from level 2 to level 1 (fig. 5–3, F).

3. The rectifiers prevent the flow of current through the control winding of core ① and the load winding of core ②.
4. The flux change during the gating half cycle of core ① is a maximum; therefore the impedance is a maximum, and the load component of current through R_L is zero. Thus, when e_c is zero, the load voltage and load component of current are zero.

Analysis with e_c Equal To e_{ac} Peak

The SECOND condition is considered to be, when $e_c = e_{ac}$ (peak). This is similar to the second condition described for the half-wave magnetic amplifier circuit. At points 3 (fig. 5–3, D), the remanent magnetism is assumed to be at level 1 for core ① and level 2 for core ② (fig. 5–3, F).

FIRST HALF CYCLE.—The applied voltage, e_{ac}, rises from zero to the maximum value during the ensuing interval of 90°, but has no effect on the flux of core ① because the control voltage, e_c, has a magnitude equal to the maximum value of e_{ac}, and a polarity opposite to that of e_{ac}. The rectifier in series with the control winding of core ① (fig. 5–3, A) prevents the flow of battery current during the time that e_c is greater than e_{ac}. Because there is no voltage across the control winding of core ① (the rectifier is essentially an open circuit), no flux change can occur in core ① from point 3 to point 4 (fig. 5–3, D), and the flux remains at level 1 (fig. 5–3, F). During the same interval, point 3 to point 4 (fig. 5–3, A, red), magnetizing current, $-I_m$, will flow through the load winding of core ② (fig. 5–3, A). The path is indicated in red. The direction of e_{ac} is such as to change the flux in core ② from negative saturation remanence level 2 to positive saturation remanence level 1 (fig. 5–3, F, red). In subsequent

gating intervals for core ②, for example, point 5 to point 6 (fig. 5–3, D, red), core ② is already saturated in a positive direction; no further flux change will occur during this gating interval, and e_{ac} will appear across R_L because the load winding offers no impedance to the flow of load current. The full value of load current will flow, and its magnitude is $\frac{e_{ac}}{R_L}$. Conduction occurs for the entire half cycle.

SECOND HALF CYCLE.—During the interval from point 4 to point 5 (fig. 5–3, D), control voltage, e_c, is of opposite polarity to that of e_{ac} (blue), and the rectifier in series with the control winding (blue) of core ② (fig. 5–3, B) will prevent the flow of battery current during the time that e_c is greater than e_{ac}. During this time there is no voltage across the control winding of core ② because the rectifier is essentially an open circuit. Thus, no flux change will occur in core ②, and the flux remains at level 1 (fig. 5–3, F).

During the same interval, point 4 to point 5 (fig. 5–3, D), current will flow in the load winding (green) of core ① (fig. 5–3, B) in a direction to drive the core further into positive saturation, level 1 (fig. 5–3, F). Since the core is already at saturation, no further flux change will occur, and e_{ac} will appear across R_L because the load winding offers no impedance to the flow of load current. The full value of load current will flow, and its magnitude is $\frac{e_{ac}}{R_L}$. Conduction occurs over the entire half cycle.

Thus, when $e_c = e_{ac}$ (peak), the full value of load current will flow through R_L, and neither core will experience any change in flux. The magnetic amplifier "fires" on each succeeding half cycle, and conduction occurs in the load windings of the cores on the negative half cycles of e_{ac} (fig. 5–3, D) point 4 to point 5 for core ①, point 5 to point 6 for core ②, and so on.

Analysis With e_c Equal To One-half e_{ac} Peak

The THIRD condition assumes that $e_c = \frac{e_{ac}}{2}$ (peak). This condition corresponds to the third condition for the half-wave circuit previously described.

FIRST HALF CYCLE.—The starting point for core ① is assumed to be level 1 (fig. 5–3, F) and for core ②, level 2. The first half cycle corresponds to the interval between points 7 and points 8 (fig. 5–3, E). From 7 to 7*a*, e_c is greater than e_{ac}, and the rectifier in series with the control winding (yellow) of core ① (fig. 5–3, A) prevents any current flow in that winding. From 7*a* to 7*b* (fig. 5–3, E, yellow), e_{ac} is greater than e_c, and a small value of magnetizing current, I_m, flows in the control winding of core ①. The extent of the flux change is dependent on the magnitude of the difference in voltage between e_{ac} and e_c across the control winding of core ①. The energy delivered to the control winding of core ① to cause the flux to reset is proportional to the yellow shaded area under e_{ac} core ① points 7*a* to 7*b* (fig. 5–3, E). It is assumed that the flux of core ① is carried from level 1 to level 3 (fig. 5–3, F, yellow). When e_{ac} reverses points 8 to 9 (fig. 5–3, E), magnetizing current, $-I_m$, flowing through the load winding (green) of core ① (fig. 5–3, B) changes the flux level from 3 to 1 (fig. 5–3, F, green). This change is assumed to occur during the interval 8 to X (fig. 5–3, E). The impedance of the load winding of core ① is high during this interval, and only the magnetizing current will flow. At point X, core ① saturates, and no further flux change occurs in that core. The impedance of the load winding of core ① drops to zero, and load current flows during the interval from X to 9 (fig. 5–3, E, green).

During the interval from 7 to 8 (fig. 5–3, E, red), the direction of e_{ac} is against the rectifier in series with the load winding of core ① and with the rectifier in series with the load winding (red) of core ② (fig. 5–3, A).

Thus, no current will flow in the load winding of core ① and current will flow in the load winding of core ②. The magnitude of this current is limited to the magnetizing current, $-I_m$, and the flux in core ② will change from negative saturation, level 2 (fig. 5–3, F, red) to positive saturation at level 1.

SECOND HALF CYCLE.—During the interval 8 to 8a (fig. 5–3, E, blue), e_c is greater than e_{ac}, and the rectifier in series with the control winding (blue) of core ② (fig. 5–3, B) prevents any current flow in that winding. The starting point for core ② is now level 1 (fig. 5–3, F). During the interval 8*a* to 8*b* (fig. 5–3, E, blue), e_{ac} exceeds e_c, and the magnetizing current, $+I_m$, will flow in the control winding of core ②. The path is shown with blue lines (fig. 5–3, B). The flux of core ② is assumed to change from level 1 to level 3 (fig. 5–3, F, blue). Point 3 is the flux level from which core ② starts when e_{ac} is in the direction of the rectifier in series with the load winding (red) of core ② (fig. 5–3, A). During the interval 9 to Y (fig. 5–3, E, red), magnetizing current flows in the load winding (red) of core ② (fig. 5–3, A), and the flux of core ② changes from level 3 to level 1 (fig. 5–3, F, red). The impedance of the load winding of core ② is high during this interval, and load current is restricted to the magnetizing current. However, at point Y, the core is saturated and no further flux change occurs. The impedance of the load winding of core ② drops to zero and load current flows during the interval Y to 10.

Thus in the full-wave circuit, simultaneous actions of gating in core ② (red) and reset in core ① (yellow) occur during one half cycle. During the second half cycle, the functions reverse and gating occurs in core ① (green) and reset occurs in core ② (blue).

In both cores, the time during which load current will flow depends on the distance from level 1 along the hysteresis loops toward level 2 (fig. 5–3, F) that the cores are reset; and this action is controlled by the magnitude

of e_c. As e_c is increased from zero to maximum, the reset distance along the hysteresis loops is decreased from maximum to zero, and the load current is increased from zero to a maximum. The amount of power delivered to the control windings is very small compared with the amount of power in the load. Hence, the power amplification is relatively large.

TRANSFER CHARACTERISTICS

In the preceding description the core material has been assumed to have a rectangular hysteresis loop with high remanence, and the rectifiers have been assumed to possess no leakage current in the opposite direction to rectification. The transfer characteristics are indicated in figure 5–4 for the ideal magnetic amplifier at (1) and for the magnetic amplifier that falls short of the ideal at (2) and (3).

Effect Of Low Remanence

Low remanence permits the core material to reset partially without regard to the magnitude of the control voltage during the reset half cycle. This action is erratic, and results in the load winding absorbing a greater part of the applied voltage during the gating half cycle, with

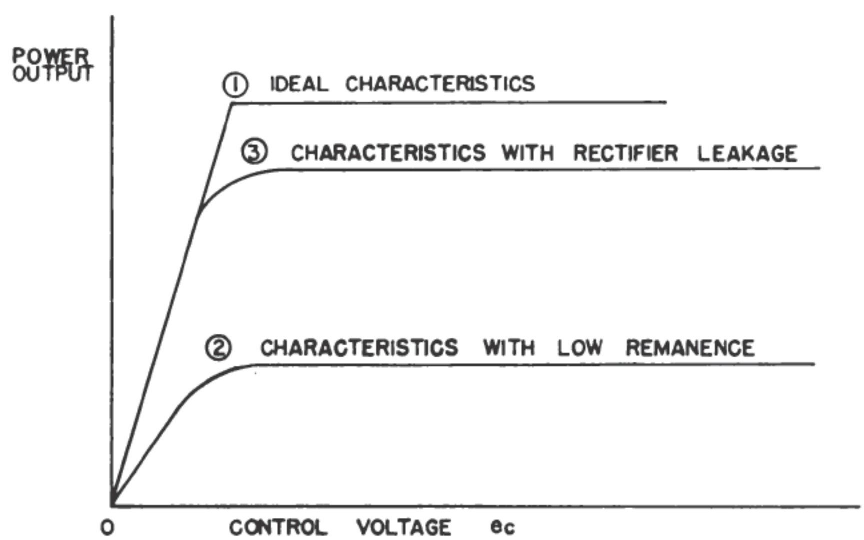


Figure 5—4.—Transfer characteristics of magnetic amplifiers.

less applied voltage available across the load when e_c is maximum. This effect is most prominent at the full-load output end of the transfer characteristic at (2) in figure 5–4.

Effect Of Rectifier Leakage

During the reset half cycle, rectifier leakage in the load circuit will allow a current to flow through the LOAD WINDING in a direction that will partially reset the core. This action will produce similar detrimental effects, at full load, to those caused by cores having low remanence. The action is most pronounced at full load because at reduced output, the voltage induced in the load winding by transformer action from the control winding during the reset half cycle is in a direction to reduce the back voltage, and therefore to reduce the leakage current through the rectifier. At full load the induced voltage in the load winding during the reset half cycle is zero, and the inverse voltage applied to the rectifier is the full value of e_{ac}. Therefore at full load the amount of rectifier leakage and reset (flux change due to leakage) is greatest. However, if the back leakage current is less than the magnetizing current required in the rectangular loop material, theoretically according to this analysis, reset will not occur.

During operation there are other factors in addition to the reverse-current leakage in rectifiers that tend to reduce the output. For example, the capacitance effect of selenium rectifiers causes a frequency sensitive action to occur. Both leakage and capacity effects increase with frequency and rectifier plate area. Thus, a magnetic amplifier that operates satisfactorily at a small current rating on a 60-cycle circuit may not produce full output when operated at 400 cycles with large current rectifiers.

FULL-WAVE CIRCUIT WITHOUT CONTROL CIRCUIT RECTIFIERS AND WITHOUT CONTROL CIRCUIT e_{ac}

In the preceding discussion of half-wave and full-wave magnetic amplifiers, the rectifiers in the load-winding

circuits and in the control-winding circuits prevent mutually induced voltages occurring in the windings of one core from affecting the flux change of the other core. Also e_{ac} is applied in the control circuits. Thus, in the full-wave bridge-type magnetic amplifier circuit of figure 5–3, when e_c is increased from zero (condition 1) to the maximum value, (condition 2) the amplifier responds in one half cycle.

If the rectifiers in the control winding circuits and e_{ac} are omitted, the circuit action will be complicated by the influence of the mutually induced voltage in the control winding of one core on the control current of the other core. The response time is increased. The basic circuits for a magnetic amplifier of this type are indicated in figure 5–5, A. The amplifier load circuit is equivalent to that of a full-wave rectifier that employs a center tapped transformer. Both cores employ square loop magnetic material. The load and control windings of both cores are assumed to have a 1:1 turns ratio.

Analysis With Zero D-c Control Voltage

The first condition to be described is that of $e_c = 0$. The remanent flux of core ① is at positive saturation remanence, ϕ_1 (fig. 5–5, B) and of core ② is at negative saturation remanence, ϕ_2.

FIRST HALF CYCLE.—On the first half cycle the direction of e_{ac} is with the rectifier in the load winding of core ①. and against the rectifier in the load winding of core ②. Therefore, current will flow in the load winding of core ① and will not flow in the load winding of core ②. The direction and magnitude of the current in the load winding of core (1) is such as to cause the flux of core ① to change from positive saturation remanence, ϕ_1, to negative saturation remanence, ϕ_2 (fig. 5–5, B).

The change of flux in core ① causes a self-induced voltage to be developed in the LOAD winding of core ① and a mutually induced voltage in the CONTROL winding of core

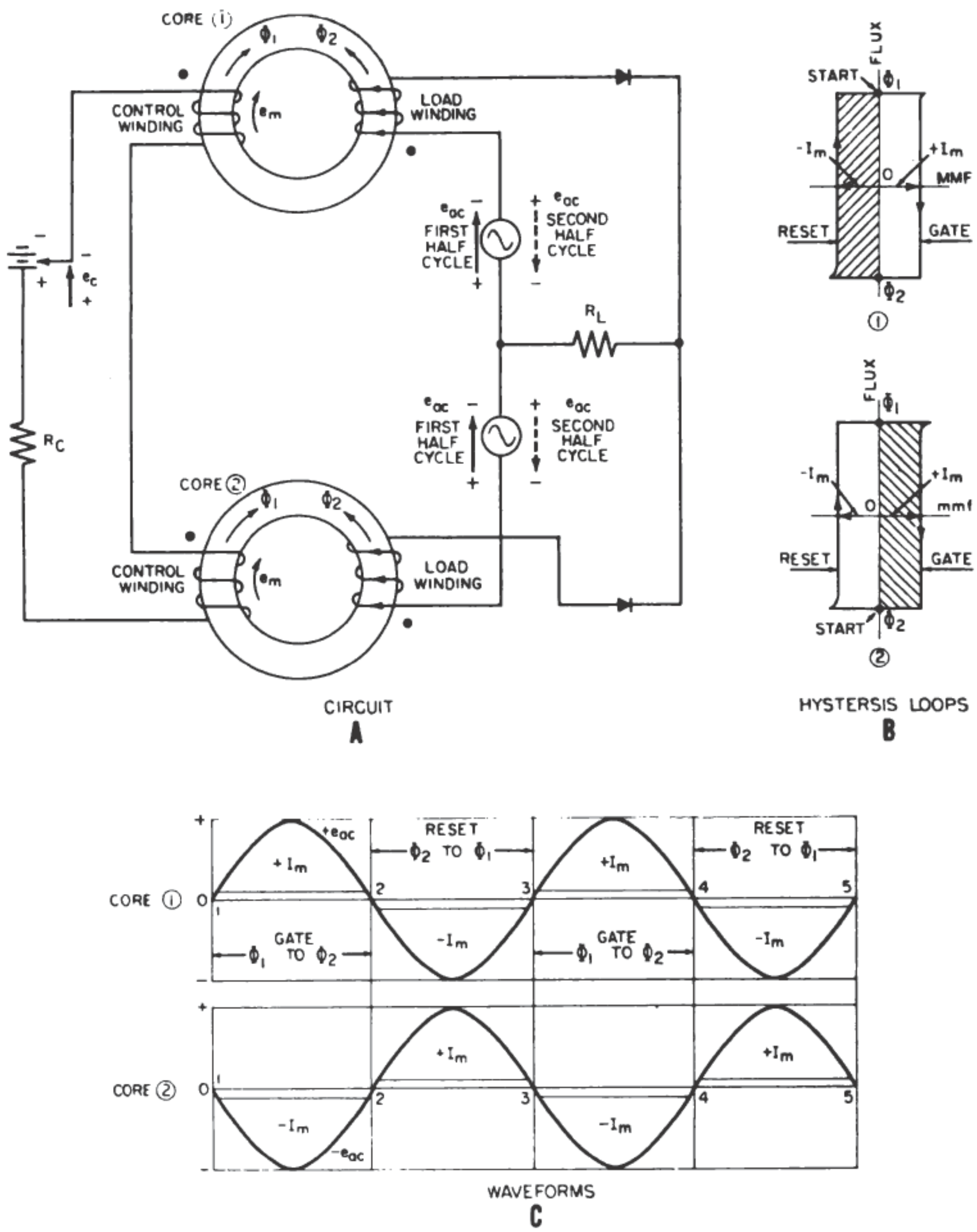


Figure 5—5.—Full-wave magnetic amplifier circuit without control circuit rectifiers.

①. The self-induced voltage in the load winding of core ① limits the current flowing through the load circuit to the magnetizing current, $+I_m$ (fig. 5–5, C) during the interval 1 to 2.

The mutually induced voltage in the control winding of core ①, during the same interval, causes a current to flow

through the control circuit and the control winding of core ② in such a direction as to reset the flux of core ② from negative saturation remanence, ϕ_2, to positive saturation remanence, ϕ_1 (fig. 5–5, B). The change in flux of core ② causes a self-induced voltage in the control winding of core ② and a mutually induced voltage in the load winding of core ②.

The self-induced voltage in the control winding of core ② limits the current in the control winding of core (2) to a small value, $-I_m$ (fig. 5–5, C) during the interval from 1 to 2. The mutually induced voltage in the load winding of core (2) is essentially equal and opposite to e_{ac}. Hence, no current flows in the load winding of core ② during this interval.

SECOND HALF CYCLE.—On the second half cycle, e_{ac} reverses polarity; the direction is with the rectifier in series with the load winding of core ② and against the rectifier in series with the load winding of core ①. Thus, current will flow in the load winding of core ②, and no current will flow in the load winding of core ①. The direction of the current in the load winding of core ② is such as to cause the flux of core ② to change from positive saturation remanence, ϕ_1, to negative saturation remanence, ϕ_2 (fig. 5–5, B).

The change of flux in core ② causes a self-induced voltage to be developed in the load winding of core ② and a mutually induced voltage in the control winding of core ②. The self-induced voltage in the load winding of core ② limits the current flowing through the load to the magnetizing current, $+I_m$ (fig. 5–5, C) during the interval from 2 to 3.

The mutually induced voltage in the control winding of core ② causes a current to flow through the control circuit and the control winding of core ① in such a direction as to reset the flux of core ① from negative saturation remanence, ϕ_2, to positive saturation remanence, ϕ_1 (fig. 5–5, B). The change of flux in core ① causes a self-induced

voltage in the control winding of core ① and a mutually induced voltage in the load winding of core ①. The self-induced voltage in the control winding of core ① limits the reset current to the magnetizing value, $-I_m$, during the interval from 2 to 3 (fig. 5–5, C). The mutually induced voltage in the load winding of core ① is equal and opposite to e_{ac} so no current will flow in the load winding of core ① during this interval.

For purposes of emphasis, the analysis is continued through the following two half cycles. At point 3 (fig. 5–5, C), e_{ac} again reverses and during the third half cycle the flux in core ① is again changed from positive saturation remanence, ϕ_1, to negative saturation remanence, ϕ_2. The self-induced voltage in the load winding of core ① limits the current to the magnetizing current, $+I_m$, during the interval 3 to 4. The mutually induced voltage in the control winding of core ① causes a current to flow through the control circuit and the control winding of core ② in a direction to reset the flux of core ② from ϕ_2 to ϕ_1 (fig. 5–5, B).

The change of flux in core ② causes a self-induced voltage to be developed in the control winding of core ② and a mutually induced voltage in the load winding of core ②. The self-induced voltage in the control winding of core ② limits the current to $-I_m$. The mutually induced voltage in the load winding of core ② is equal and opposite to e_{ac}. Hence, no current flows in the load winding of core ② during the interval 3 to 4 (fig. 5–5, C).

A condition of equilibrium is reached. The control winding in core ② resets the flux in core ② from ϕ_2 to ϕ_1 at the same time that the load winding in core ① gates the load, and the flux of core ① changes from ϕ_1 to ϕ_2. During the next half cycle the functions reverse and reset occurs in core ① and gating occurs in core ②. This action occurs as long as $e_c = 0$. The load current is a small value, I_m, and e_{ac} appears across the load windings because of the high impedance which they present to the flow of load cur-

rent. The load voltage is zero and the output power is zero.

Effect of D-c Control Voltage

The effect of a d-c control voltage on the operation of the magnetic amplifier is to unbalance the condition of equilibrium and to increase the amplifier output.

FIRST HALF CYCLE.—At point 5 (fig. 5–5, C), the flux in core ① is at ϕ_1, and in core ② is at ϕ_2 (fig. 5–5, B). The first half cycle of e_{ac} (fig. 5–6, A), the flux in core ① changes from ϕ_1 toward ϕ_2 (fig. 5–6, B), but e_c is applied across the control windings of both cores in series and is of a polarity to cause both cores to go toward negative saturation remanence, ϕ_2.

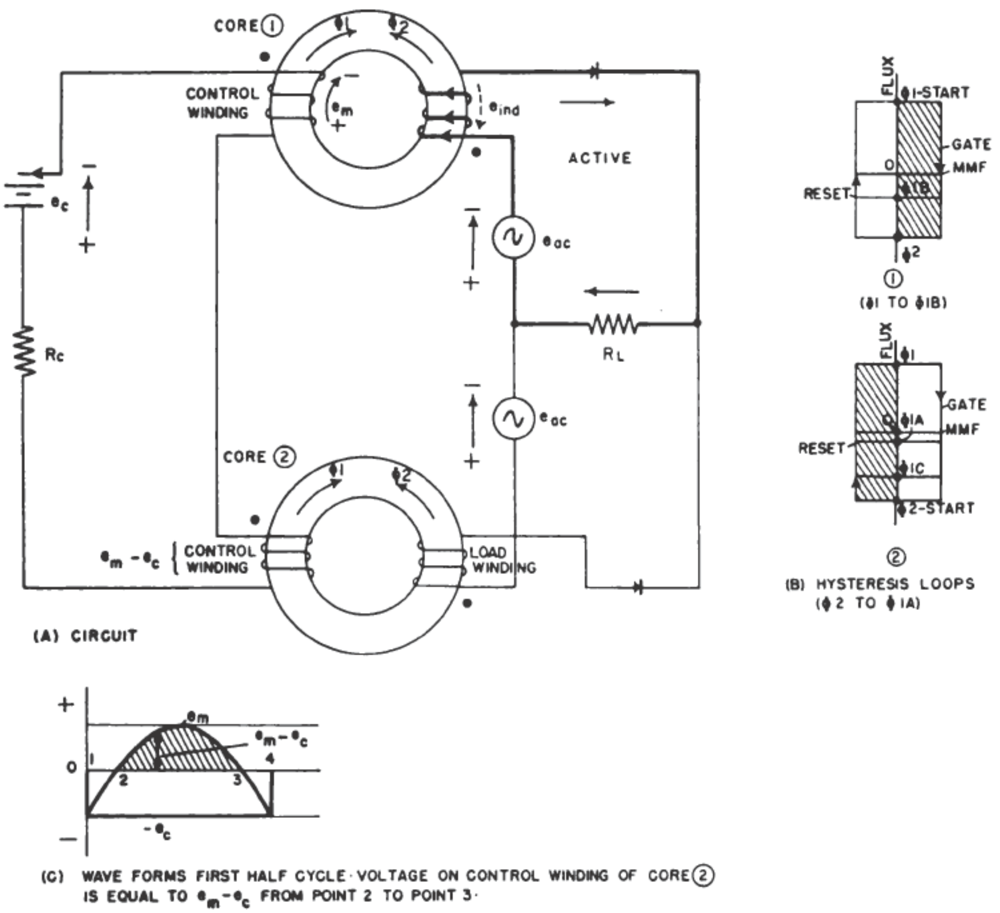


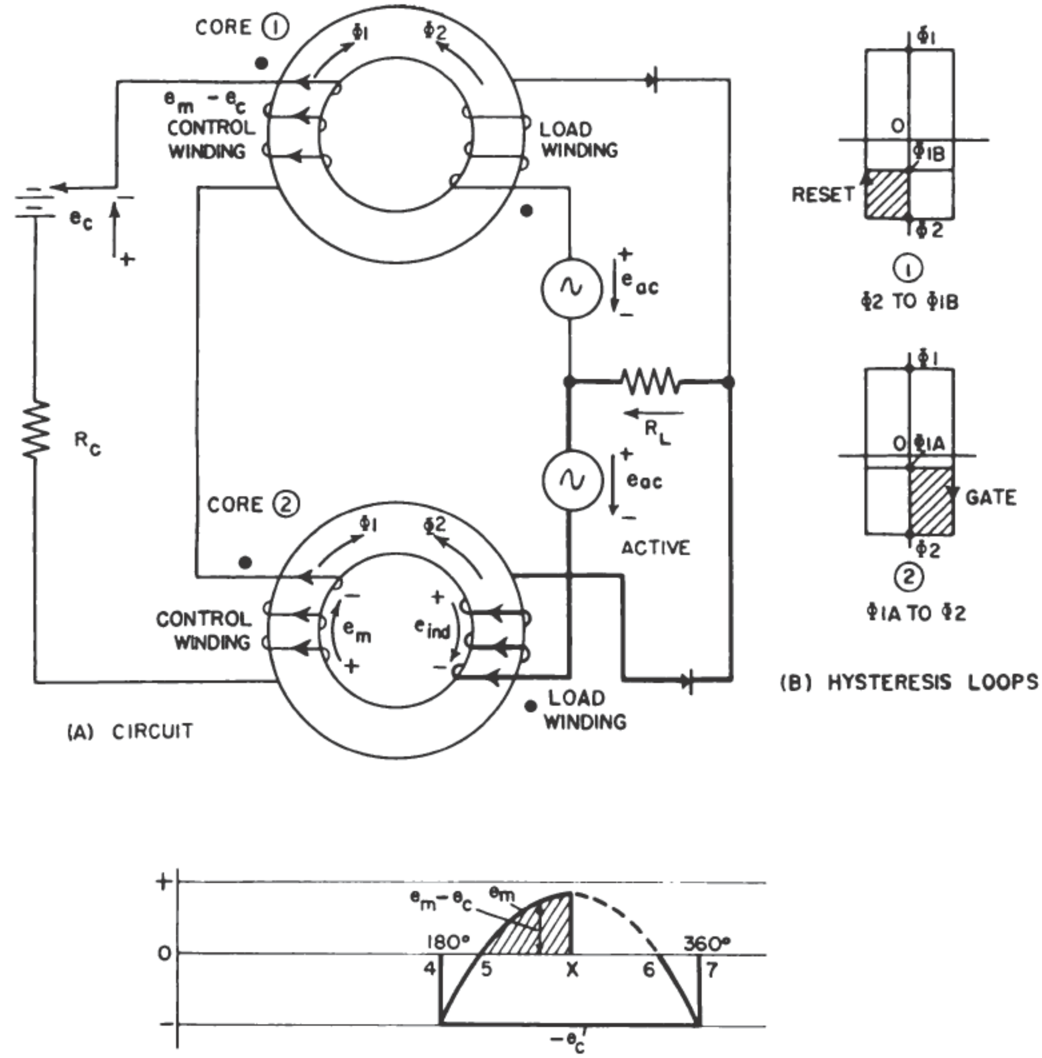
Figure 5—6.—Analysis of magnetic amplifier for first half cycle of e_{ac} (no rectifiers in control circuit).

The voltage on the control winding of core ② is the difference between e_c and the mutually induced voltage, e_m, in the control winding of core ①. From point 1 to point 2 (fig. 5–6, C), e_c is greater than e_m and the flux of core ② remains at ϕ_2 (fig. 5–6, B). From point 2 to point 3, e_m is greater than e_c and reset occurs in core ②. The amount of reset is proportional to the shaded area under the curve of voltage applied to the control winding of core ②. Thus, core ② flux resets, for example, from ϕ_2 to ϕ_{1A}. It does not reset all the way to ϕ_1 because e_c is active in reducing the effect of e_m.

SECOND HALF CYCLE.—The second half cycle (fig. 5–7, A) core ②, flux is changed in the load winding from ϕ_{1A} to ϕ_2 (fig. 5–6, B). The voltage applied to the control winding of core ① is $e_m - e_c$, and the reduced average value of e_m (less range of flux change in core ②) causes less reset in core ① than occurred in condition 1, when e_c was zero. The energy represented by the shaded area under the voltage curve (fig. 5–7, C), applied to the control winding of core ① point 5 to point X, is less than the shaded area under the curve of voltage applied to the control winding of core ② (fig. 5–6, C), point 2 to 3. Thus reset of core ① flux occurs from ϕ_2 to ϕ_{1B} (fig. 5–7, B).

The following half cycle, gating occurs in core ① from ϕ_{1B} to ϕ_2 (fig. 5–6, B) and reset occurs in core ② from ϕ_2 to ϕ_{1C}. Each succeeding half cycle, the total flux change becomes less, and for example within approximately 10 cycles after e_c is increased from zero to the maximum value corresponding to full-load output, both cores reach negative saturation remanence and remain there until e_c is reduced.

Thus, for condition 2, e_c is increased until the full-load value of current flows through R_L. After a condition of equilibrium is reached, the flux of core ① will be at negative saturation remanence, ϕ_2 (fig. 5–5, B) as determined by the polarity of e_c in relation to the control winding of core ①. Similarly the flux of core ② will be at negative



(C) WAVEFORMS SECOND HALF CYCLE; VOLTAGE ON CONTROL WINDING OF CORE ① IS EQUAL TO $e_m - e_c$ FROM POINT 5 TO POINT X.

Figure 5–7.—Analysis of magnetic amplifier for second half cycle of e_{ac} (no rectifiers in control circuit).

saturation remanence, ϕ_2. No flux change will occur in either core. Both load windings will conduct the full value of load current on alternate half cycles of applied voltage due to the arrangement of the rectifiers in the load circuit. The waveforms for the steady state condition are indicated in figure 5–8, A, and for partial output (fig. 5–8, B).

For example, if this magnetic amplifier is employed as a reactance dimmer for theater lighting, when e_c is zero

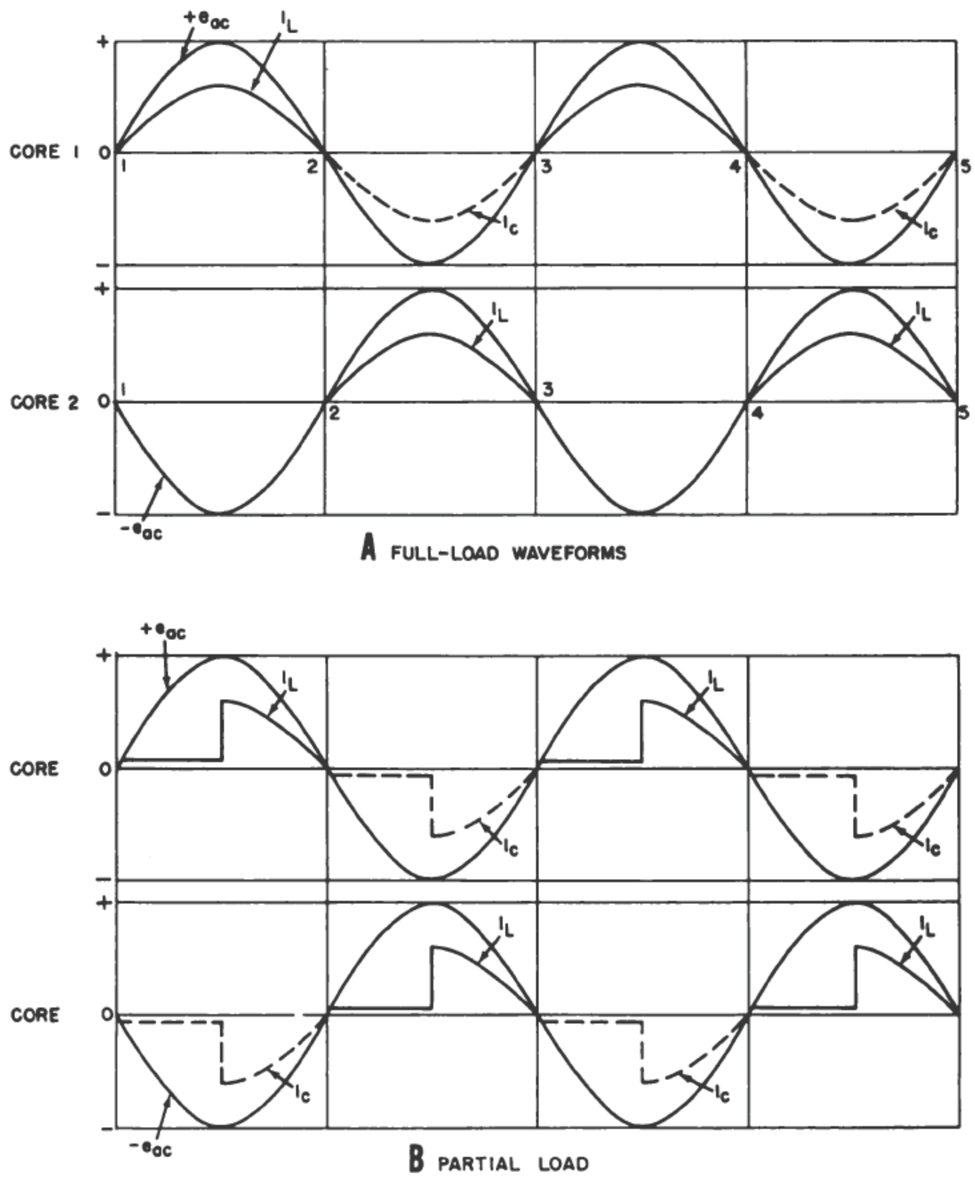


Figure 5—8.—Full-load and partial-load waveforms for magnetic amplifier (no rectifiers in control windings).

the lights will be dim. As e_c is increased from zero to the value corresponding to full-load output, the lights will increase in brightness after a time lag, following the change of e_c. As e_c is increased, the flux change in each core occurs for a lesser part of the time in each half cycle. Thus, the pulses of load current increase and the lights brighten.

QUIZ

1. Name the five advantages of the magnetic amplifier over the electron tube amplifier.
2. Name the four disadvantages of the magnetic amplifier.
3. Name the five components that usually comprise magnetic amplifiers.
4. Name the two principal types of nickel-iron alloys that are used as cores for saturable reactors.
5. Hysteresis loops for these materials are characterized by what general features?
6. Give the trade names of three high-permeability core materials.
7. Give the trade names of three grain-oriented core materials.
8. (a) When a magnetizing force is applied to a grain-oriented material so that the flux is in the direction of the grains, what shape of hysteresis loop is obtained? (b) What is the relative permeability from zero magnetization up to the knee of the curve? (c) What is the relative degree of saturation above the knee of the curve?
9. (a) The actions of what respective elements in the thyratron tube are comparable to the actions of the control and load windings in the magnetic amplifier? (b) Why is the load winding connected in series with the load? (c) Why is a control winding used?
10. How is the flow of load current controlled during each half cycle in a magnetic amplifier?
11. How is the magnetization affected during the reset half cycle?
12. What is the relative instantaneous polarity of the dotted ends of two windings on the same core?
13. Why are rectifiers placed in the control and load circuits in the basic magnetic amplifier?

IN FIGURE 5–2, FOR THE FIRST HALF CYCLE (QUESTIONS 14 THROUGH 19):

14. (a) What is the relative direction and (b) polarity of the induced voltage with respect to the polarity marked terminals?
15. What is the relative direction of the induced voltages with respect to that of the applied voltage (the same or opposite)?
16. What is the action of the rectifier in the load circuit?

17. What is the arithmetic relation between the applied voltage, the inverse voltage on the load circuit rectifier, and the mutually induced voltage in the load circuit?

18. What is the relative direction of the mmf of the control winding with respect to the remanent (residual) core flux?

19. Upon what two factors does the extent of the core flux change depend?

IN FIGURE 5–2, FOR THE FIRST HALF CYCLE WHEN $e_c = 0$ (QUESTION 20 THROUGH 22):

20. What is the relative extent of the core flux change?

21. (a) Current flow through which winding causes core flux change? (b) What is this action called?

22. What action in the control winding limits the current in that circuit to a small value?

IN FIGURE 5–2, FOR THE SECOND HALF CYCLE WHEN $e_c = 0$ (QUESTIONS 23 THROUGH 26):

23. What is the action of the rectifier in the control circuit?

24. What is the action of the rectifier in the load circuit?

25. What is the relation between the mmf of the load winding and the residual core flux?

26. What is the relative magnitude of the impedance presented by the load winding to the circuit containing R_L?

IN FIGURE 5–2, FOR THE FIRST HALF CYCLE WHEN $e_c =$ peak e_{ac} (QUESTIONS 27 THROUGH 29):

27. (a) What is the effect of e_{ac} on the core flux? (b) Why?

28. What action in the control circuit prevents the flow of battery current?

29. (a) What is the relative magnitude of the voltage across the control winding? (b) Why?

IN FIGURE 5–2, FOR THE SECOND HALF CYCLE WHEN $e_c =$ PEAK e_{ac} (QUESTIONS 30 THROUGH 31):

30. Why is there no flow of current in the control winding?

31. (a) What is the relation between the direction of the mmf of the load winding as determined by the polarity of e_{ac} and the residual flux, ϕ_1? (b) What relative flux change occurs? (c) What relative impedance is presented to the load current? (d) Across which component in the load circuit does e_{ac} appear? (e) What is the relative magnitude of the load current?

IN FIGURE 5–2, WHEN $e_c = \frac{1}{2}$ PEAK e_{ac}:

32. (a) Why is no voltage applied across the control winding during the interval from point 1 to point 2 (fig. 5–2, E)? (b) Why does a voltage exist across the control winding during the time interval from point 2 to point 3 (fig. 5–2, E)? (c) What is happening to the core flux during the interval from point 2 to point 3? (d) What is happening to the core flux during the interval from point 4 to point 5? (e) What is the relative magnitude of the impedance of the load winding during the interval from point 4 to point 5? (f) What is the name given to the current flow through the load winding during the interval from point 4 to point 5? (g) At point 5, what happens to the core flux? (h) What is the relation between the shaded area represented under the $+e_{ac}$ curve and that represented by the right-hand shaded area of the hysteresis loop? (i) What is the relation between the shaded area represented under the $-e_{ac}$ curve and that represented by the left-hand shaded area of the hysteresis loop? (j) What determines how much of the gating half cycle will be nonconducting? (k) How do the average load current and voltage vary with respect to the control voltage, e_c?

IN FIGURE 5–3, FOR THE FIRST HALF CYCLE WHEN $e_c = 0$:

33. (a) The two circuits that are active (conducting) are ________. (b) What is the relative extent of the flux change in core ①? (c) What is the relative extent of the flux change in core ②? (d) What is the relative magnitude of impedance developed by the load winding of core ②? (e) What are the relative magnitudes of load voltage and current? (f) What is the action of the rectifiers in the control winding of core ② and the load winding of core ①?

IN FIGURE 5–3, FOR THE SECOND HALF CYCLE WHEN $e_c = 0$:

34. (a) The two circuits that are active (conducting) are ________. (b) What is the relative extent of the flux change in core ②? (c) What is the relative extent of the flux change in core ①? (d) What is the relative magnitude of the impedance developed by the load winding of core ①? (e) What are the relative magnitudes of load voltage and load current? (f) What is the action of the rectifiers in the control winding of core ① and the load winding of core ②?

IN FIGURE 5–3, FOR THE FIRST HALF CYCLE (POINTS 3 TO 4) WHEN $e_c = e_{ac}$ PEAK:

35. (a) At the start of the half cycle the remanent magnetism is assumed to be at level ________ for core ① and level ________ for core ②. (b) Why does e_{ac} have no effect on the flux of core ① as far as the control winding of core ① is concerned? (c) What is the action of e_{ac} on the load winding of core ②?

36. (a) In subsequent gating intervals for core ②, for example, points 5 to points 6 (fig. 5–3, D) (red), what is the action of e_{ac} on the load winding of core ②? (b) What relative value of load current will flow (in terms of e_{ac} and R_L)?

IN FIGURE 5–3, FOR THE SECOND HALF CYCLE (POINTS 4 TO 5) WHEN $e_c = e_{ac}$ PEAK:

37. (a) What relative voltage is developed across the control winding of core ②? (b) Why? (c) What relative flux change occurs in core ① as far as the effect of the load winding of core ① is concerned? (d) Why? (e) What relative magnitude of load current flows in the load winding of core ① (in terms of e_{ac} and R_L)?

38. (a) In the example of figure 5–3, when $e_c = e_{ac}$ peak, conduction through the load windings of the two cores occurs on which half cycle of e_{ac} (positive or negative)? (b) Does the "firing" action of core ① occur simultaneously with that of core ②? (c) Why?

39. At the start of the half cycle, points 7 to 8 (fig. 5–3, E), the remanent magnetism (fig. 5–3, F) is assumed to be at level ________ for core ① and level ________ for core ②.

40. (a) From points 7 to 7*a* (fig. 5–3, E), what is the relative magnitude of current in the control winding of core ①? (b) Why?

41. (a) From points 7*a* to 7*b* (fig. 5–3, E), what is the relative magnitude of current in the control winding of core ①? (b) Why? (c) How is the extent of the flux change in core ① from points 7*a* to 7*b* (control winding, yellow) related to e_{ac} and e_c? (d) From 7*a* to 7*b*, it is assumed that the magnetizing current in the control winding of core ① causes the flux of core ① to be carried (fig. 5–3, F) from level ________ to level ________.

42. (a) During the interval from points 8 to X (fig. 5–3, E), the magnetizing current flowing through the load winding of core ① causes the flux of core ① (fig. 5–3, F) to be carried from level ________ to level ________. (b) What happens to core ① at point X (fig. 5–3, E) as a result of the action of the magnetizing current in the load winding of core ①? (c) What change in impedance of the core ① load winding occurs at point X (fig. 5–3, E)?

43. (a) During the interval from 7 to 8 (fig. 5–3, E), what relative value of current flows in the load winding of core ① (fig. 5–3, A)? (b) Why?

44. (a) During the interval from 7 to 8 (fig. 5–3, E), what relative value of current flows in the load winding of core ② (fig. 5–3, A)? (b) Why?

45. (a) During the interval 8 to $8a$ (fig. 5–3, E), what is the relative magnitude of the current flow in the control winding of core ② (fig. 5–3, B) (blue)? (b) Why?

46. (a) During the interval from $8a$ to $8b$ (fig. 5–3, E), what relative value of current flows in the control winding of core ②? (b) Why? (c) The flux of core ② is assumed to change from level ________ to level ________ (fig. 5–3, F).

47. (a) During the interval from 9 to Y (fig. 5–3, E), what relative value of current flows in the load winding of core ②? (b) The flux of core ② is assumed to change from level ________ to level ________ (fig. 5–3, F). (c) What is the relative magnitude of the impedance of the load winding of core ② during this interval? (d) What change in impedance of the core ② load winding occurs at point Y (fig. 5–3, E)? (e) Why?

48. (a) In both cores, the time during which load current will flow depends upon what core flux action (fig. 5–3, F)? (b) How is this action related to e_c? (c) What is the relative magnitude of the ratio of the power output of the load windings to the power input of the control windings?

49. (a) What is the effect of rectifier leakage on the power output? (b) What is the relative effect of low remanence on the power output? (c) What is the effect of rectifier capacitance on the power output at high frequencies?

50. What is the effect on the response time of a magnetic amplifier when the control circuit rectifiers and the control circuit e_{ac} are omitted?

CHAPTER 6

MAGNETIC-AMPLIFIER APPLICATIONS

Magnetic amplifiers are widely used aboard ship as regulators to control the voltage, current, and frequency of the main propulsion plant and of auxiliary units. Also they will be used extensively in the future as a complete replacement for the thyratron and amplidyne controls in servo systems aboard ship. Speed-regulation equipment that utilizes magnetic amplifiers is also installed aboard ship to provide a closely regulated 400-cycle power supply for certain interior communications and fire control equipment. In this chapter only voltage and speed-regulator units will be discussed.

VOLTAGE-REGULATION EQUIPMENT

If an a-c generator is operating at constant speed and with constant field excitation, the terminal voltage will vary with changes in the load. When the load increases, the generator voltage decreases, and when the load decreases, the generator voltage increases. To obtain proper operation of the motors and other equipment supplied by the ship's service a-c generators, the generator voltage must be maintained practically constant from no load to full load. This action is automatically accomplished by means of voltage-regulation equipment comprising a (1) static excitation system, (2) voltage-regulator unit, and (3) manual-control and auxiliary unit.

Static Excitation System

PRINCIPLES.—The principles of a 3-phase static excitation system are explained by the equivalent single-phase circuit of a 3-phase generator as shown in figure 6–1. In figure 6–1, A, E_t is equal to the generator terminal voltage, E_g is the generated voltage, X_L is the armature inductive reactance, IX_L is the armature inductive reactance voltage drop, and I is the load current. When I flows, E_t is the vector difference between E_g and IX_L. The armature resistance drop is neglected because it is small compared to the armature reactance drop.

When the generator is operating under no-load conditions, $E_t = E_g$ because no current flows, and $IX_L = 0$.

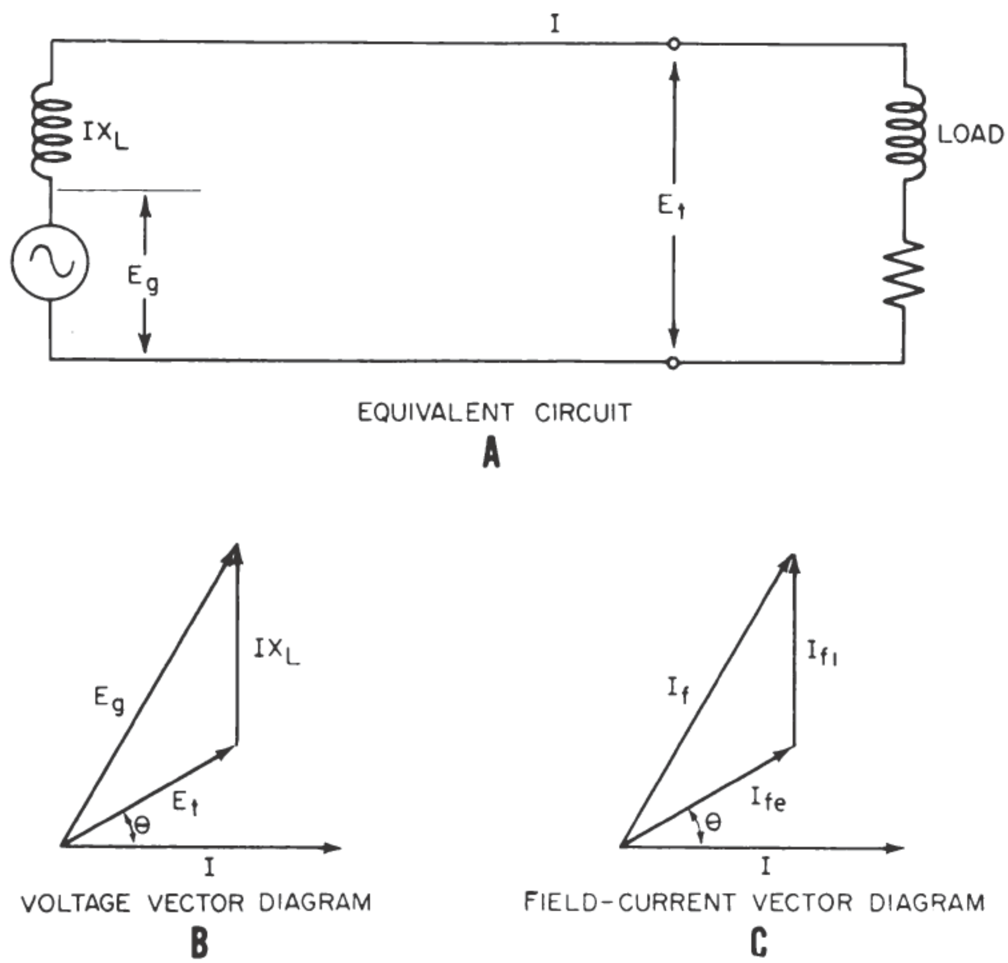


Figure 6—1.—Equivalent single-phase circuit of a 3-phase generator.

Conversely, when the generator is operating under short-circuited conditions, $E_g = IX_L$ because E_t is zero.

The vector diagram for a lagging power factor load is indicated in figure 6–1, B, where I lags E_t by angle θ. The IX_L drop in the generator armature leads I by an angle of 90°. The vector sum of IX_L and E_t is equal to E_g. If I increases, IX_L will increase, and E_t will decrease. If θ increases, and the load is inductive, E_t will decrease. Below saturation the generated voltage is always proportional to the d-c field current, I_f. Thus, if E_t falls, I_f must be increased in order to increase E_g and prevent further decrease of E_t.

An ideal automatic excitation system for an a-c generator should provide the proper amount of field current necessary to maintain the terminal voltage constant for any specified load and power-factor changes. Such an excitation system will also provide field current components that correspond to the three voltage vector components, E_g, E_t, and IX_L (fig. 6–1, B). Thus, I_f may be regarded as made up of the components, I_{fi} and I_{fe} (fig. 6–1, C). These components form a triangle that is similar to the voltage triangle of figure 6–1, B.

A simplified static (no moving parts) excitation system is shown in figure 6–2. The a-c generator is self-excited —that is, its field current is obtained through rectifiers from the alternator output. A saturable reactor is used in series with the load to automatically control the field current of the generator under varying load conditions. The 3-phase circuit (fig. 6–2, A) consists of a 3-phase saturable current transformer CT1, 3-phase potential transformer $T1$, linear reactors $4X$, $5X$, $6X$, and field rectifiers $CR8$. The equivalent single-phase circuit is indicated in figure 6–2, B. In the simplified field-excitation circuit (fig. 6–2, C), E represents the output voltage of potential transformer $T1$, X_1 represents the reactance of reactor $1X$, and R represents the generator field resistance. In addition, the saturable current transformer is

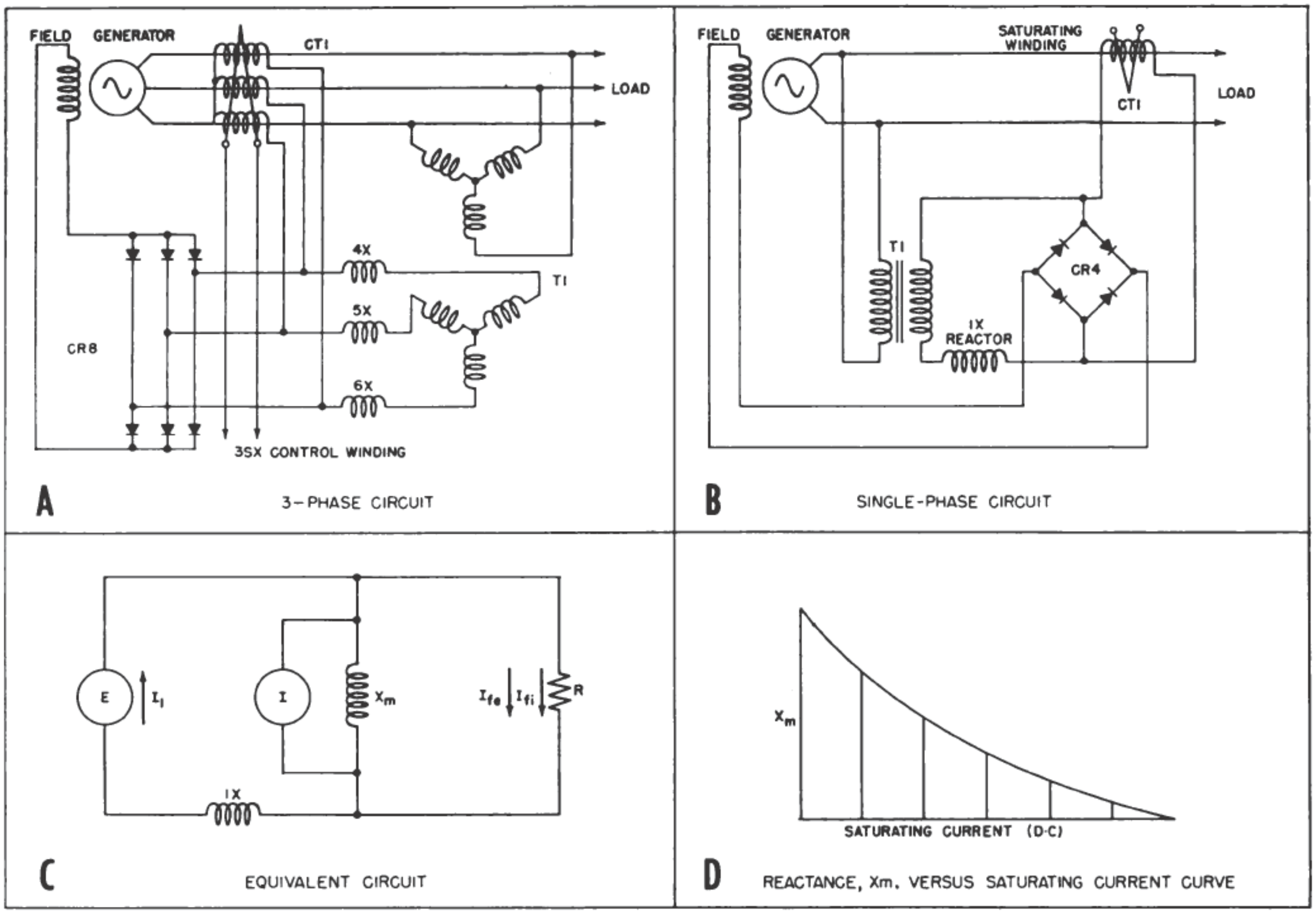


Figure 6—2.—Static excitation system.

represented by the current source, I, in parallel with the magnetizing reactance of its secondary X_m. For the sake of simplicity, the rectifiers have been omitted.

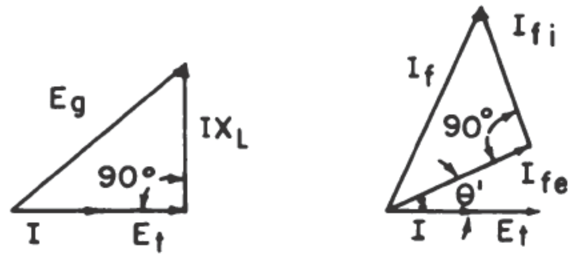
The voltage source, E, produces the current, I_1, which flows through the reactor, $1X$. A portion of this current flows through the secondary reactance, X_m, of the saturable current transformer, and a portion flows through the generator field, R. This current through R is the generator-field component, I_{fe}, which is proportional to the terminal voltage, E_t, of the a-c generator.

When a load current flows in the generator, current I, which is always directly proportional to the load current, is induced in the secondary of the saturable current transformer. A portion of this current flows through the secondary reactance, X_m, of the saturable current transformer; a portion flows through reactor $1X$ and voltage source E; and the remainder flows through the generator field, R. This current through R is the generator-field component, I_{fi}, which is proportional to the load current of the a-c generator.

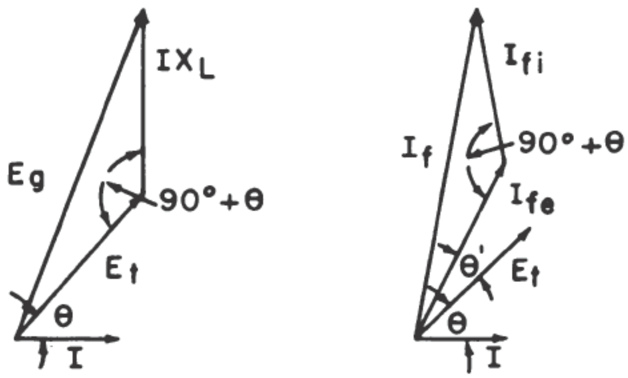
Secondary reactance X_m of the saturable current transformer can be controlled by changing the flux density of the iron in the current transformer. This change in flux density is accomplished by changing the magnitude of the direct current in a separate saturating winding on the current transformer (fig. 6–2, A). When the saturating current is increased, the iron of the current transformer will become more saturated, X_m will decrease, and the generator-field current and terminal voltage will decrease because of the shunting effect of X_m (fig. 6–2, C). The relation between X_m and the d-c saturating current is indicated in figure 6–2, D.

OPERATION.—The characteristics of the generator and the excitation system are shown by the vector diagrams in figure 6–3. The excitation system will function in accordance with these vector diagrams by proper selection of the circuit parameters.

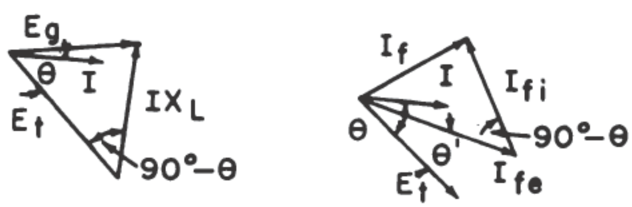
GENERATOR EXCITATION-SYSTEM



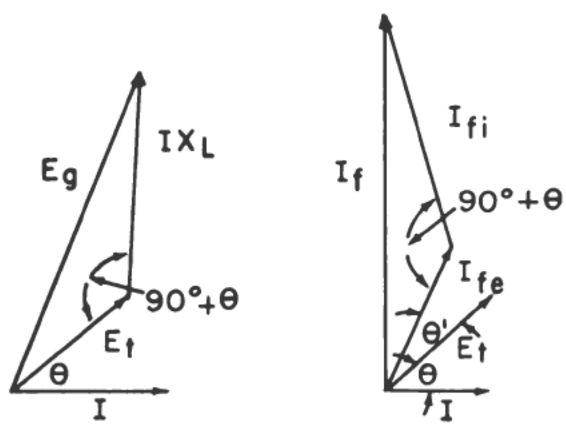
A UNITY POWER FACTOR AT RATED LOAD



B 0.5 POWER FACTOR LAGGING AT RATED LOAD



C 0.5 POWER FACTOR LEADING AT RATED LOAD



D 0.5 POWER FACTOR LAGGING AT TWICE RATED LOAD

Figure 6—3.—Generator- and excitation-system characteristics.

The vector diagrams (fig. 6–3, A) show the relations for unity power factor at rated load in the a-c generator and in the excitation system respectively. The generator-field component, I_{fe}, is proportional to E_t in phase and in magnitude; whereas the generator field component, I_{fi}, is proportional to the generator IX_L drop in phase and in magnitude. Hence, the total field current, I_f, is proportional to the required E_g in phase and in magnitude. The angle θ', being determined by the excitation-system circuit characteristics, is constant, and has no effect on the final magnitude of the a-c generator-field current, I_f.

Similar vector diagrams show the relations in the a-c generator and the excitation system respectively for a power factor of 0.5 lagging at rated load (fig. 6–3, B); a power factor of 0.5 leading at rated load (fig. 6–3, C); and a power factor of 0.5 lagging at twice rated load (fig. 6–3, D). In each case, I_{fe} is proportional in phase and in magnitude to E_t, I_{fi} is proportional in phase and in magnitude to IX_L, and I_f is proportional in phase and in magnitude to E_g.

The generator-field components, I_{fi} and I_{fe}, combine to produce the total field current, I_f, which is rectified (fig. 6-2, B). The phase angle of I_{fi} and I_{fe} are important, only in the sense that they determine the magnitude of I_f.

When the generator is operating under open-circuit (no-load) conditions, I_f is supplied entirely from the voltage source, E, (fig. 6–2, C) because the generator IX_L drop is zero. Thus, the generator-field component, I_{fi}, is zero. On the other hand, when the generator is operating under short-circuit conditions, I_f is supplied entirely from the current source, I, (fig. 6–2, C) because E_t is zero. Thus, the generator-field component, I_{fe}, is zero.

If the value of the magnetizing reactance, X_m, of the saturable current transformer is changed for any given operating condition, I_f is changed also because X_m is in parallel with the generator field, R, (fig. 6–2, C). Thus, increasing X_m forces more current through the generator field, whereas decreasing X_m shunts more current away

from the generator field, R. For a given load and power factor, increasing I_f results in increasing E_t, and similarly, decreasing I_f results in decreasing E_t. Hence, E_t can be controlled by controlling the value of X_m.

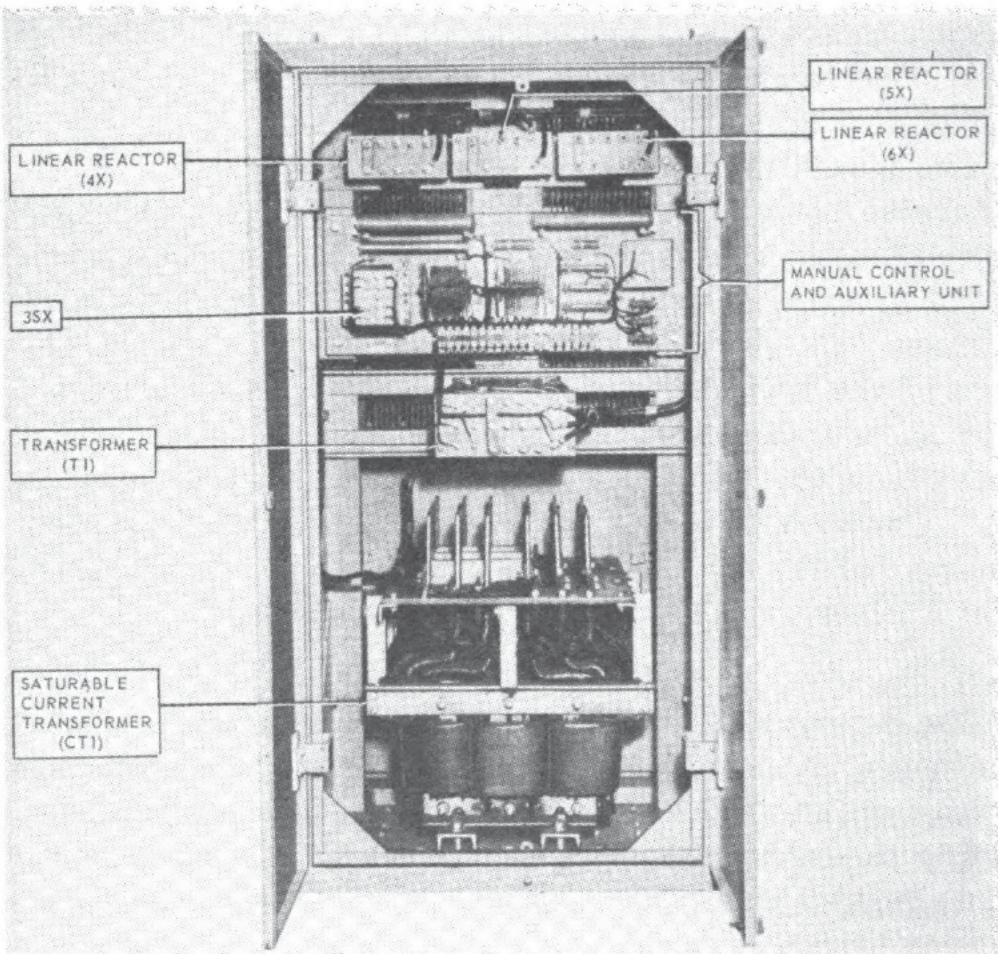
The magnitude of the secondary reactance, X_m, of the saturable current transformer can be changed independently of load-current change by varying the direct current in the saturating winding of the saturable current transformer. If the d-c saturating current is increased, the core of the current transformer becomes more saturated and X_m will decrease. This action shunts more current away from the field (fig. 6–2, C), resulting in a decrease in E_t. Conversely, if the saturating current is decreased, the core of the current transformer becomes desaturated, and X_m increases, resulting in an increase in E_t.

Voltage-Regulator Unit

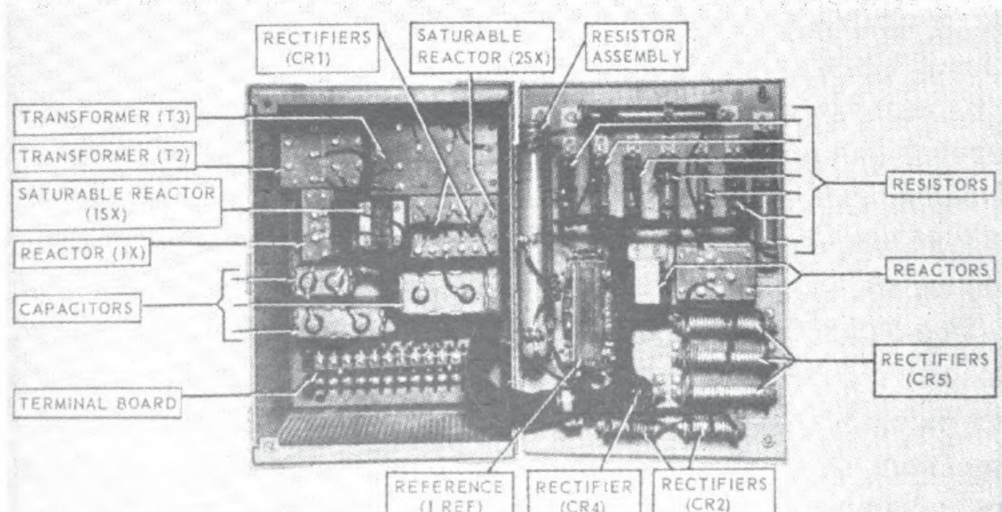
The d-c supply to the saturable current transformer is controlled by a voltage regulator. The static excitation system without the regulator would not be capable of supplying the exact amount of field current required to maintain constant generator terminal voltage under all operating conditions.

The static excitation and voltage regulation equipment for a ship's service generator utilizing magnetic amplifiers is illustrated in figure 6–4. This equipment provides for manual and automatic voltage regulation of the ship's service generator voltage and consists of (1) static excitation system, (2) manual control and auxiliary unit, (3) automatic control unit, and (4) the necessary voltage adjusting rheostats and transfer switches.

The STATIC EXCITATION EQUIPMENT (fig. 6–4, A) is enclosed in a steel cabinet provided with two hinged doors for access to the interior. The equipment mounted in the front of the cabinet includes the line reactors, voltage transformer, and the saturable current transformer. The equipment mounted in the rear of the cabinet (not shown) includes the field rectifiers and terminal block.



A STATIC EXCITATION SYSTEM AND MANUAL CONTROL AND AUXILIARY UNIT



B AUTOMATIC CONTROL UNIT

Figure 6—4.—Static-excitation and voltage-regulation equipment.

The MANUAL CONTROL and AUXILIARY UNIT (fig. 6–4, A) is mounted in the front of the cabinet that houses the static excitation equipment. This unit includes the third stage (3SX) of the magnetic amplifier and the required resistors, rectifiers, and terminal boards.

The AUTOMATIC CONTROL UNIT (fig. 6–4, B) is enclosed in a separate steel cabinet designed for bulkhead mounting and provided with a removable cover for access to the interior. This unit includes the first and second stages (1SX and 2SX) of the magnetic amplifier and the necessary transformers, rectifiers, resistors, capacitors, and terminal board.

The control equipment for the static excitation and voltage regulation equipment is illustrated in figure 6–5. This

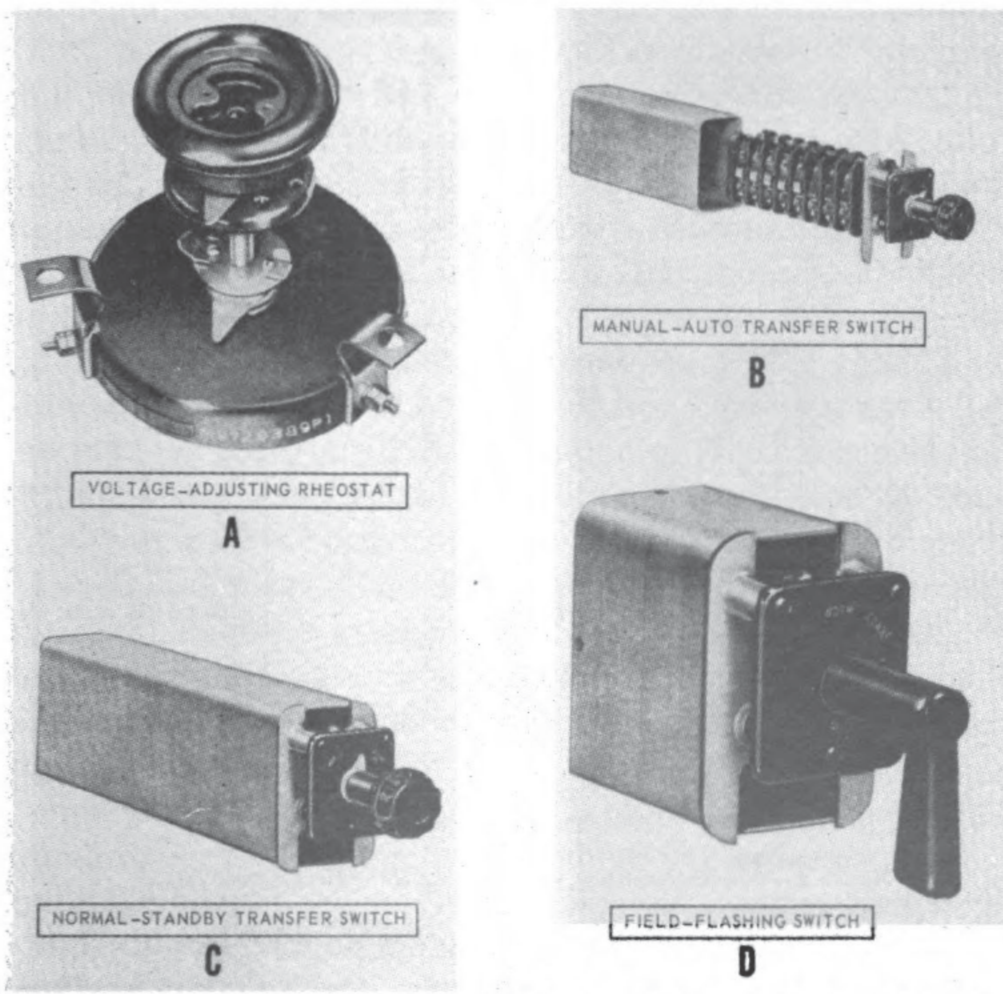


Figure 6—5.—Static-excitation and voltage-regulation control equipment.

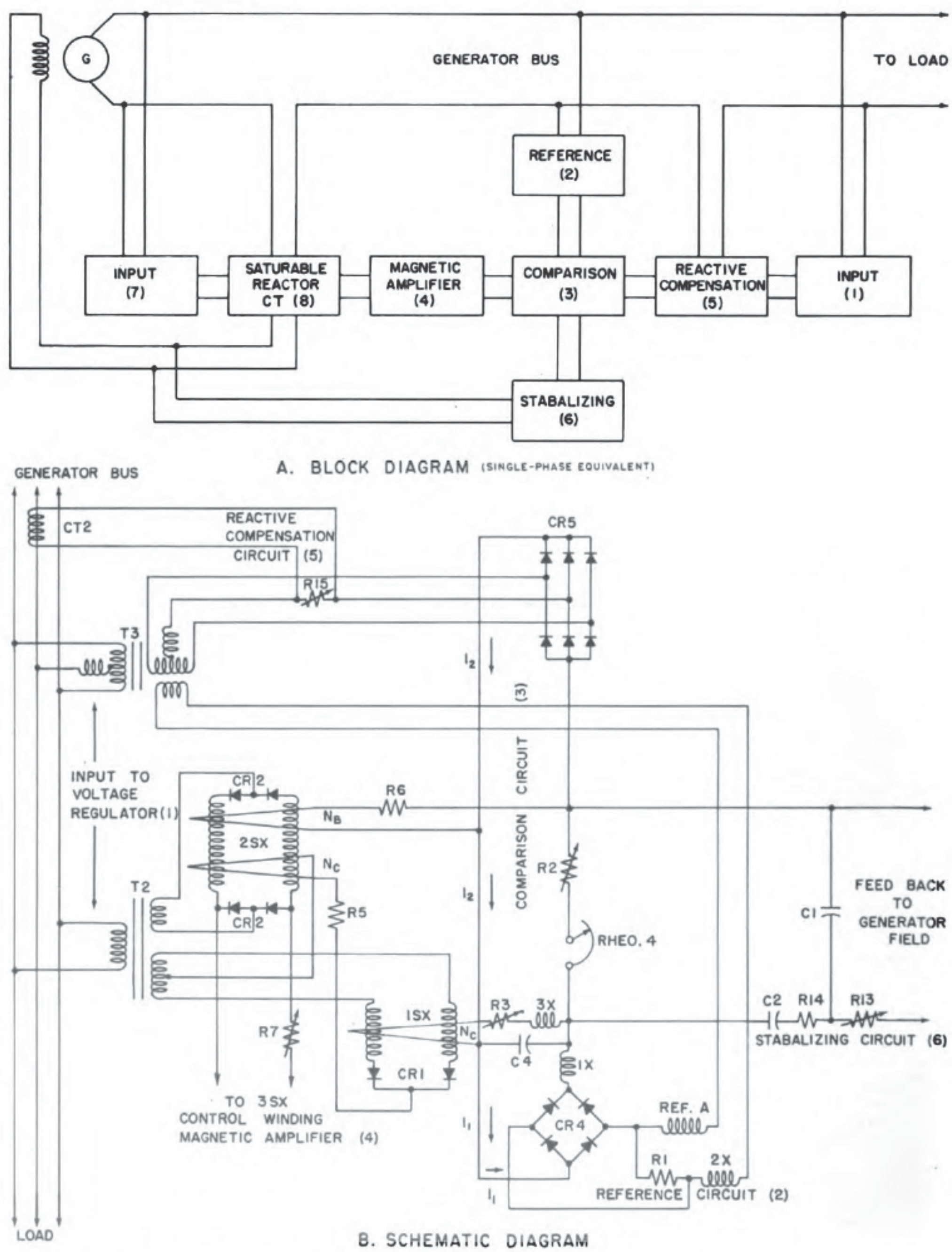


Figure 6—6.—Elementary voltage-regulator circuit analysis.

equipment is mounted on a separate panel and includes the (1) voltage-adjusting rheostat (fig. 6–5, A), (2) manual-automatic transfer switch (fig. 6–5, B), (3) normal-standby transfer switch (fig. 6–5, C), and (4) field-flashing switch (fig. 6–5, D).

A block diagram of the voltage regulator and static excitation system is indicated in figure 6–6, A. The voltage regulator consists of the following circuits: input circuit (1), reference circuit (2), comparison circuit (3), magnetic-amplifier 1*SX* and 2*SX* circuits (4), reactive-compensation circuit (5), and stabilizing circuit (6). The associated static excitation system consists of input (7) and saturable reactor current transformer (8).

The magnetic amplifiers (fig. 6–6, B) are arranged in a manner similar to the conventional cascade connection of two or more electron-tube amplifier stages. Thus, the load winding of the first-stage magnetic amplifier 1*SX*, supplies the control winding of the second stage, 2*SX*, and the load winding of the second stage supplies the control winding of the 3*SX* stage located in the manual control and auxiliary unit (not shown in this figure). Finally the output of the 3*SX* stage supplies the saturating winding of the saturable current transformer and thus controls the magnitude of the generator-field current. In this manner the overall amplification of control current is equal to the product of the gain of each stage, and, in this regulator, is of the order of 1000.

INPUT CIRCUIT.—The voltage-regulator input circuit (fig. 6–7) consists essentially of a single-phase transformer *T*2 and two T-connected transformers, *T*3, the primaries of which are connected to the 3-phase a-c generator bus.

One of the T-connected transformers is provided with two secondary windings, one of which is a separate single-phase secondary. The T-connected secondaries supply a 3-phase signal, which is an indication of the a-c generator terminal voltage, to the signal rectifier, *CR*5. The single-

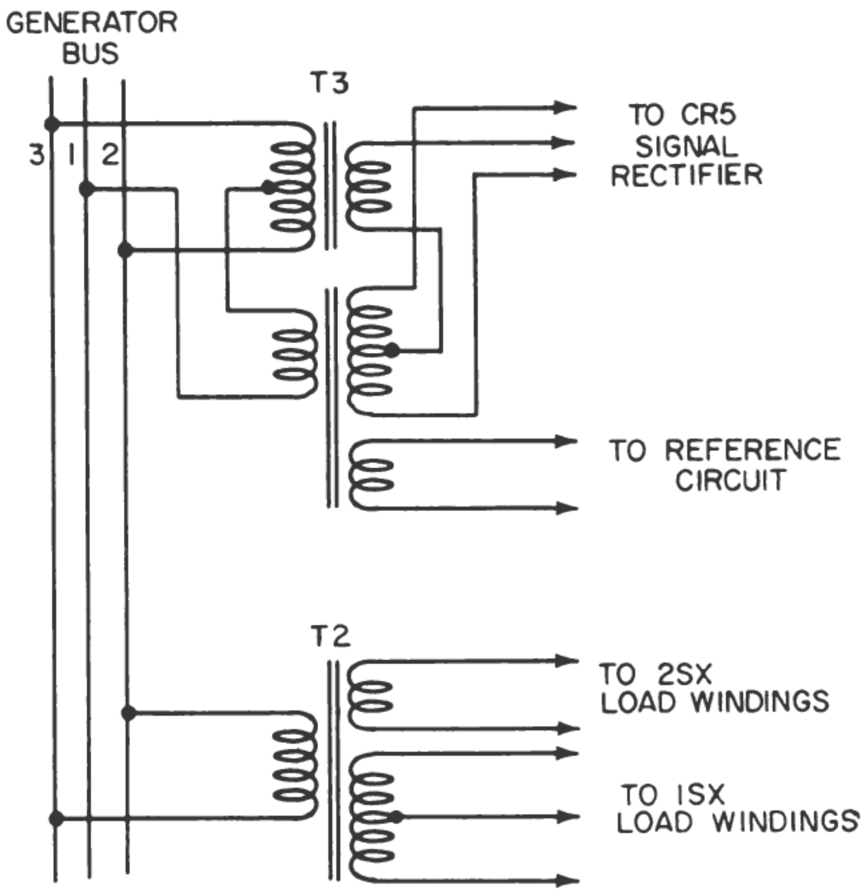


Figure 6–7.—Voltage-regulator input circuit.

phase secondary supplies power to the reference circuit. The T-connection (similar to the open-delta connection) assures continuity of the power supply to the reference circuit in the event of the failure of any one phase of the generator bus.

Transformer *T*2 is provided with two single-phase secondary windings. These windings supply the first (1*SX*) and the second (2*SX*) stages of the magnetic amplifier.

REFERENCE CIRCUIT.—The reference circuit (fig. 6–8, A) supplies a nearly constant current to the comparison circuit. It consists of reference winding *A*, resistor *R*1, and reactor 2*X*. Reference winding *A* comprises two coils connected in series, A_1 and A_2, on the outside legs of the magnetic core (fig. 6–8, B). The middle leg of this core consists of a permanent magnet in parallel with a

magnetic shunt that has an air gap. The mmf of the permanent magnet causes flux to be established through each of the outer legs of the core and the shunt. The magnitude of the permanent-magnet mmf is sufficient to bias the outer legs of the core considerably above the knee of the magnetization curve, point 1 (fig. 6–8, C).

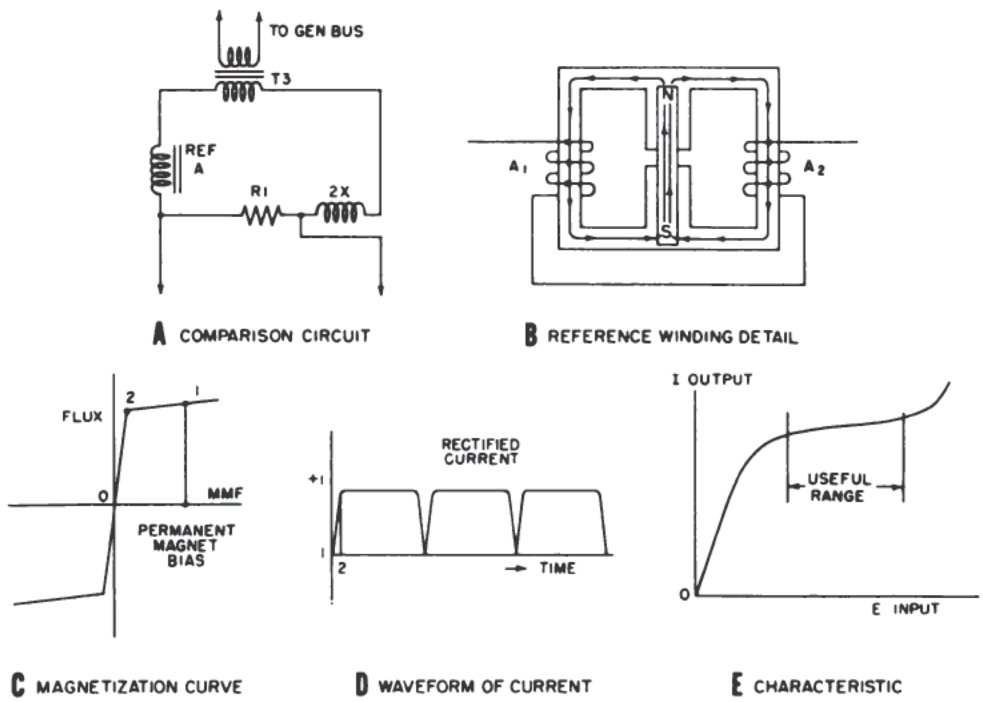


Figure 6—8.—Voltage-regulator reference circuit.

During one half cycle, the current in coil A_1 aids the mmf of the permanent magnet, and the current in A_2 opposes it. Coil A_1 drives the core further into saturation, and coil A_2 drives the core toward the knee of the magnetization curve, point 2, (fig. 6–8, C). Until the knee is reached, no flux change occurs. The impedance is low and the current increases abruptly, 1 to 2, (fig. 6–8, D). When point 2 is reached, the coil suddenly offers a high impedance (due to the flux change) to any further increase in current, and the current is limited to a nearly constant value.

During the other half cycle, the reverse action occurs in the two coils. Hence, the current is limited in both direc-

tions. The alternating voltage produces a square-wave current, which is rectified into a d-c output that remains constant over the useful range of a-c input voltage (fig. 6–8, E).

The output current of the reference circuit increases slightly as the input frequency is raised. Reactor $2X$ is used to compensate for this effect. Reactor $2X$ increases its reactance with frequency by the same amount that the effective impedance of the reference winding, A, decreases. Thus, the total effective impedance remains constant, and the output current is independent of any change in frequency.

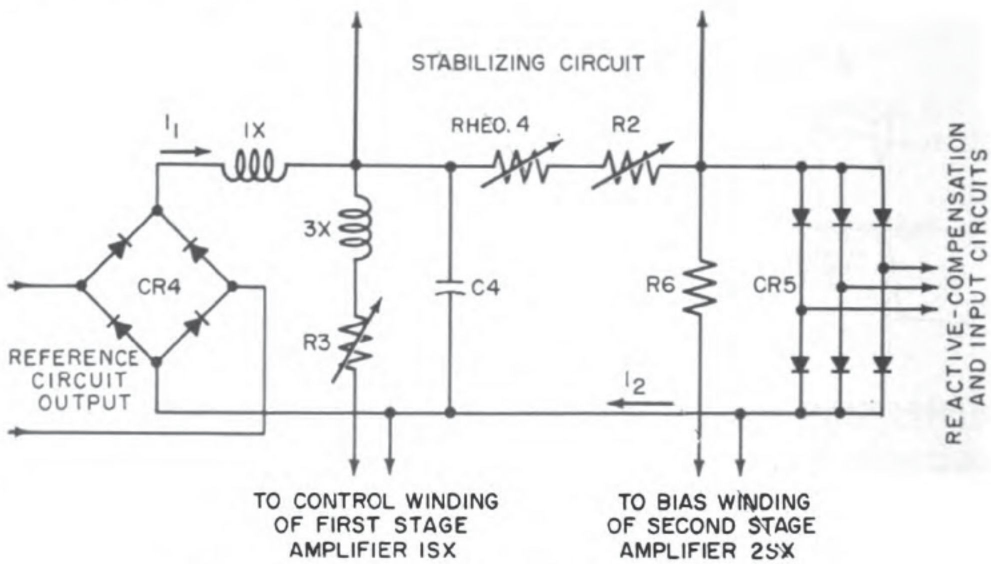


Figure 6—9.—Voltage-regulator comparison circuit.

COMPARISON CIRCUIT.—The comparison circuit (fig. 6–9) consists essentially of rectifiers $CR4$ and $CR5$, reactors $1X$ and $3X$, variable resistors $R2$ and $R3$, main automatic voltage-adjusting rheostat Rheo 4, and resistor $R6$.

The output current of the reference circuit is rectified by rectifier $CR4$. This rectified reference current, I_1, flows in the first-stage control winding of the magnetic amplifier. The output current, I_2, of the signal rectifier, $CR5$, flows in the opposite direction through the same

control winding. Hence, the reference current, I_1, that remains comparatively constant for small changes in voltage is compared against the signal current, I_2, which varies widely for small changes in voltage. The difference between these two currents is effective in controlling the first stage, 1*SX*, of the magnetic amplifier.

The voltage-adjusting rheostat, Rheo 4, is used to alter the signal current, I_2, without disturbing the reference current, I_1, and thus to change the magnitude of the current difference through the control winding of the magnetic amplifier. This action causes the voltage regulator to maintain a different value of terminal voltage. Rectifier *CR*5 also functions to supply the second-stage bias winding of the magnetic amplifier.

MAGNETIC-AMPLIFIER 1*SX* AND 2*SX* CIRCUITS.—Changes in the generator voltage produce changes of current in the comparison circuit of the order of milliamperes. These current changes are amplified by the magnetic amplifier to values of the order of amperes and fed to the saturating windings of the saturable current transformers, *CT*1, (fig. 6–2). The magnetic amplifier consists of three stages. The first stage, 1*SX*, and the second stage, 2*SX*, (fig. 6–10, A) are contained in the automatic control unit. The third stage, 3*SX*, not shown in this figure, is contained in the manual-control and auxiliary unit.

The magnetic amplifier, with constant power-supply voltage and frequency, conducts earlier or later in the cycle of applied voltage, depending on the current in the control windings. The output load current is the average value of the rectified current pulses, which are controlled by the d-c signal in the control winding. The d-c signal can be changed in magnitude either in a positive or in a negative direction.

If, under normal operating conditions, the magnetic amplifier has a current of $-I_{cd}$ milliamperes (fig. 6–10, B) in its control circuit, the corresponding load current is

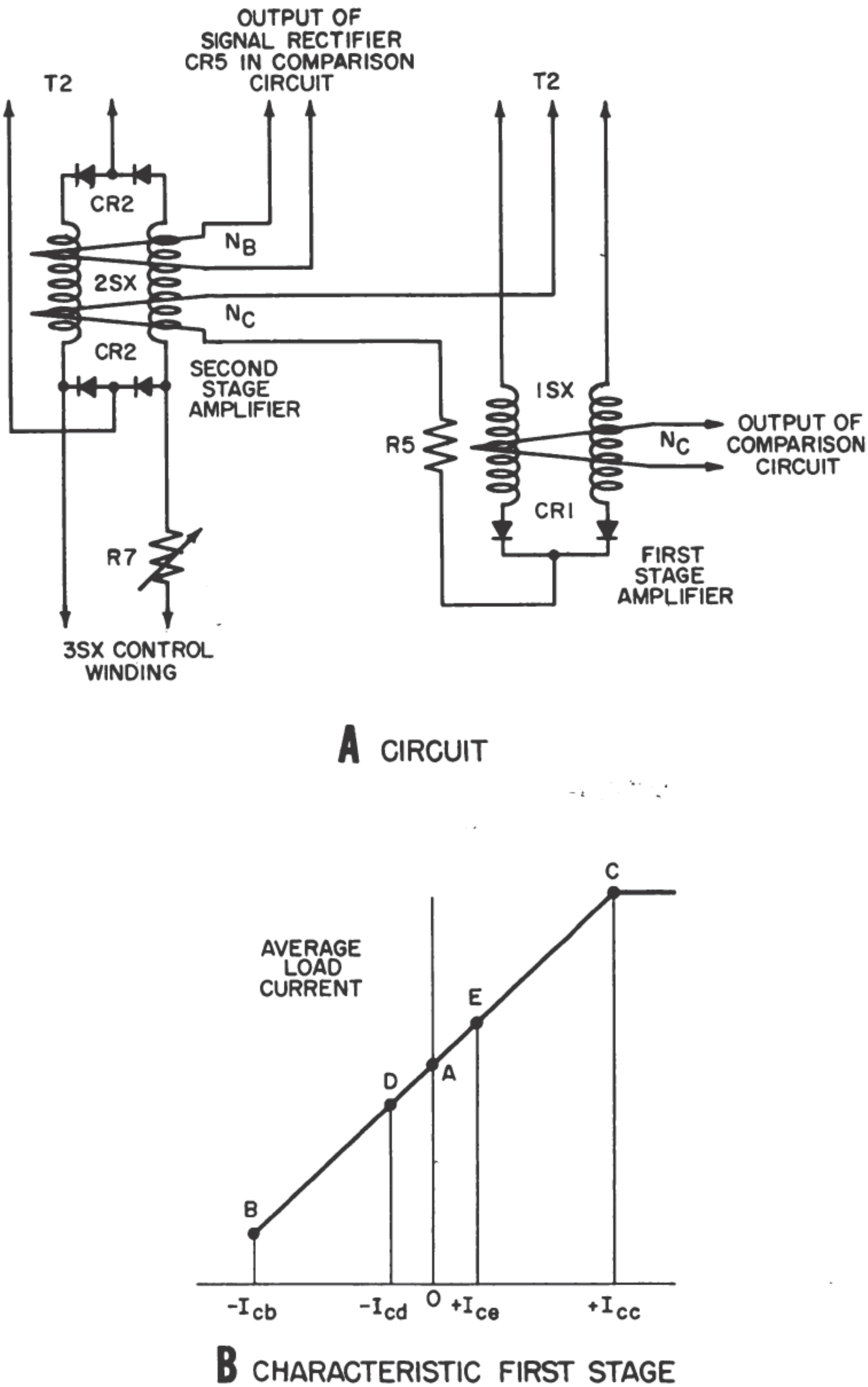


Figure 6—10.—Voltage-regulator magnetic-amplifier 1SX and 2SX circuits.

D amperes. Thus the control current (fig. 6–9) that flows in the control winding of the first stage amplifier, $1SX$, is I_{cd} milliamperes greater than the signal current, I_2, (fig. 6–9). If for some reason the generator terminal voltage should rise, the signal current, I_2, would increase proportionally, and the current, $I_2 - I_1 = I_{cd}$, in the control winding of the first-stage amplifier might go from $-I_{cd}$ milliamperes to zero, or it might go positive, for example, to $+I_{ce}$ (fig. 6–10, B), causing the average d-c load current to increase. The increase in the load current would increase the d-c saturating current in the control winding of $CT1$ (fig. 6–2, A). This action would decrease X_m (fig. 6–2, D) and decrease the field current because of the increased shunting effect of X_m (fig. 6–2, C). Thus the weakened field would reduce the generated voltage and check the rise in terminal voltage.

REACTIVE COMPENSATION CIRCUIT.—To obtain satisfactory parallel operation of two or more generators with individual voltage-regulator control, the regulators must (1) maintain nearly constant voltage and (2) provide proper division of the reactive load. The magnetic voltage regulator tends to maintain constant voltage irrespective of the reactive load or the power factor of the regulated machine. However, to obtain proper division of the reactive current between generators for load conditions, it is necessary to bias the voltage element of the regulator with reactive current.

The reactive-compensation circuit (fig. 6–11, A) provides individual voltage-drop compensations in order to secure proper division of the reactive load. This circuit consists of the single-phase current transformer, $CT2$, and the variable resistor, $R15$. Line voltage and current vectors for unity power-factor load are indicated in figure 6–11, B. The voltage vectors for the T-connected transformers, $T3$ (fig. 6–6B) are indicated in figure 6–11, C.

The average voltage output of transformer $T3$ is roughly proportional to the area of the triangle, 4–5–6. Unity

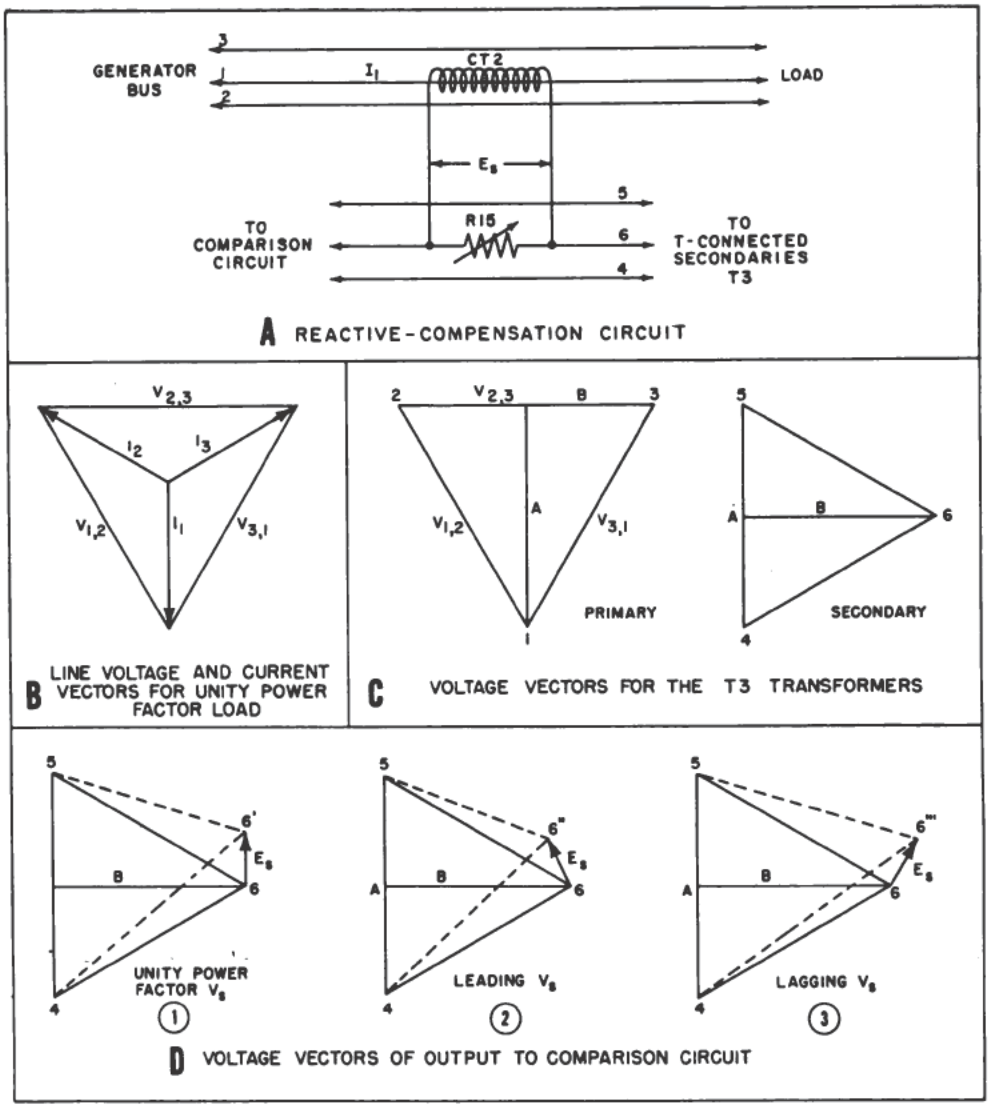


Figure 6—11.—Voltage-regulator reactive-compensation circuit analysis.

power-factor line current I_1 will induce voltage E_s across $R15$ in phase with I_1. The voltage vector diagram for this condition is indicated in figure 6–11, D (1). The voltage that the regulator will now try to regulate is proportional to the area of triangle 4–5–6′. Since this area is not appreciably different from that of triangle 4–5–6, the voltage appears normal and the regulator takes no action.

If in addition to its load, the generator draws a leading (under excited) reactive circulating current when operating in parallel with another generator, the voltage, E_s,

across $R15$ will change its phase position as shown in figure 6–11, D (2). The regulator will now try to regulate the average output voltage of $T3$, which is proportional to the area of triangle 4–5–6″. Because this area is less than the area of triangle 4–5–6, the voltage appears low, and the regulator will supply more excitation to the generator field until the condition of under excitation that produces a leading circulating current is corrected.

If the generator draws a lagging (over-excited) reactive circulating current when it is operating in parallel with another generator, the voltage, E_s, across $R15$ will change its phase as shown in figure 6–11, D (3). The average output voltage is now proportional to the area of triangle 4–5–6‴. Since this area is greater than the area of triangle 4–5–6, the voltage appears high, and the regulator will remove excitation from the generator until the condition of over excitation that produces a lagging circulating current is corrected.

The voltage-drop compensation method of regulating the reactive current of generators that operate in parallel tends to introduce a slight drop in the system voltage as the lagging reactive-current load on the system increases. The amount of this voltage drop depends on the amount of signal E_s that is applied to the regulator and on the power factor of the load.

STABILIZING CIRCUIT.—In order to assure stable operation of the system during automatic regulation, the stabilizing circuit shown in figure 6–12 is used. This circuit receives a signal from a change in generator-field voltage and feeds a signal into the comparison circuit in the form of a voltage across the voltage-adjusting rheostat, 4R, (fig. 6–6, B).

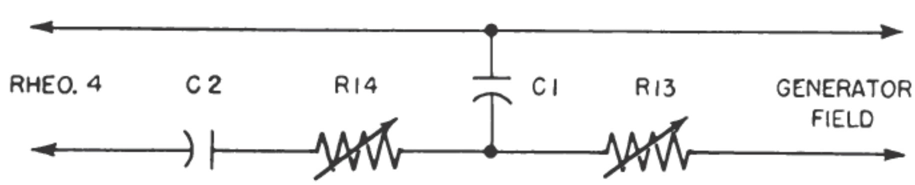


Figure 6—12.—Voltage-regulator stabilizing circuit.

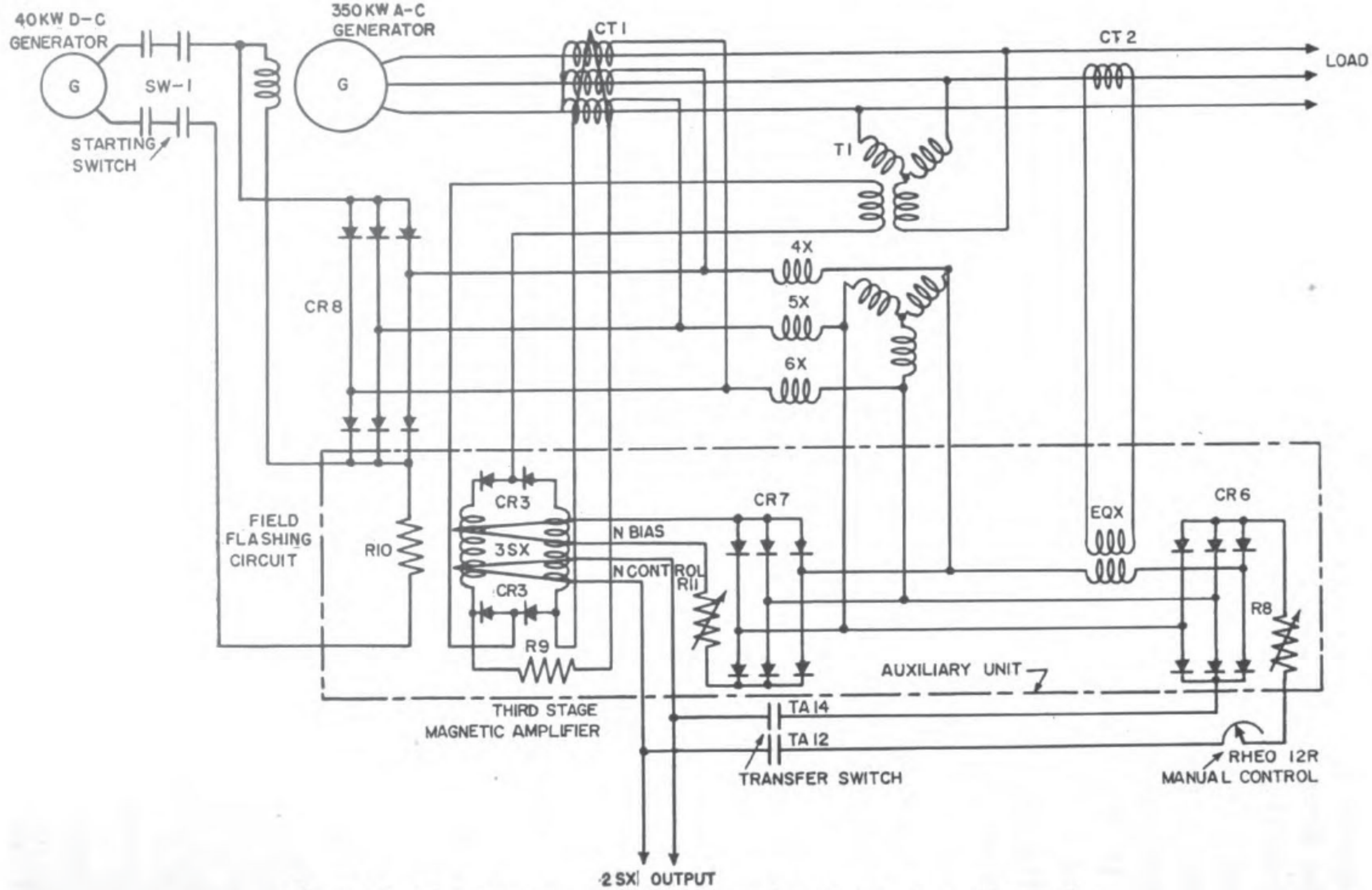


Figure 6—13.—Voltage-regulator manual-control and auxiliary unit.

When the regulator and excitation system operate to change the field voltage, the stabilizing circuit introduces a voltage into the comparison circuit in such a manner as to restrain the regulator from making excessive field-voltage correction, and thereby hunting is prevented.

Manual-Control and Auxiliary Unit

The manual-control and auxiliary unit, shown with the static excitation system (fig. 6–13) provides (1) manual control when the regulator is not in use, (2) a third stage of amplification when the regulator is in use, and (3) a field-flashing circuit including a separate 40-kw d-c generator.

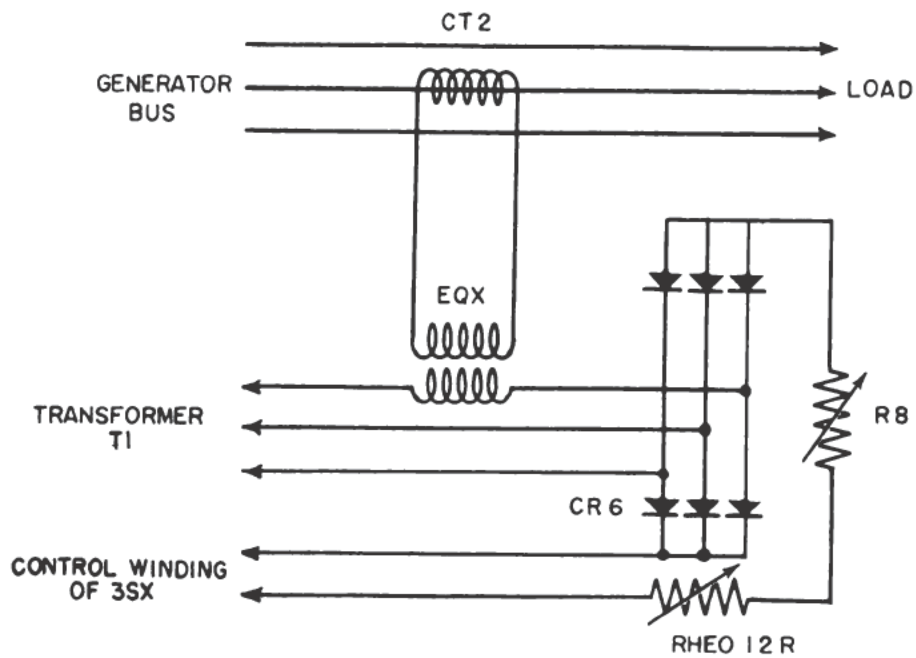


Figure 6—14.—Voltage-regulator manual-control circuit.

MANUAL-CONTROL CIRCUIT.—The manual-control circuit (fig. 6–14) includes equalizing reactor *EQX*, rectifier *CR*6, variable resistor *R*8, and manual voltage-adjusting rheostat, Rheo. *R*12. The output of the 3-phase transformer, *T*1, is rectified by rectifier *CR*6, the output of which controls the third stage, 3*SX*, of the magnetic amplifier, and in turn the excitation system.

Reactive compensation is provided by the equalizing

reactor, EQX, which is energized by the output of current transformer $CT2$. Because the reactive line current varies the magnitude of the average voltage to rectifier $CR6$, the operation of this circuit is similar to the voltage-regulator reactive-compensation circuit analysis (fig. 6–11). The voltage-adjusting rheostat, Rheo. $R12$, is used to adjust the generator output voltage.

When rheostat $R12$ is turned through its full range the generator voltage should vary between plus 5 percent and minus 10 percent of the nominal (rated) voltage, from no load to 125 percent of full load. If the proper range of voltage adjustment is not obtained, resistor $R8$ should be adjusted until the desired range is obtained.

MAGNETIC-AMPLIFIER $3SX$ CIRCUIT.—The third stage of the magnetic amplifier, $3SX$ (fig. 6–15) is used as the third stage of amplification in the previously described voltage-regulator unit; it is used as the only stage of amplification when the system is operating on manual control.

FIELD-FLASHING CIRCUIT.—The field-flashing circuit

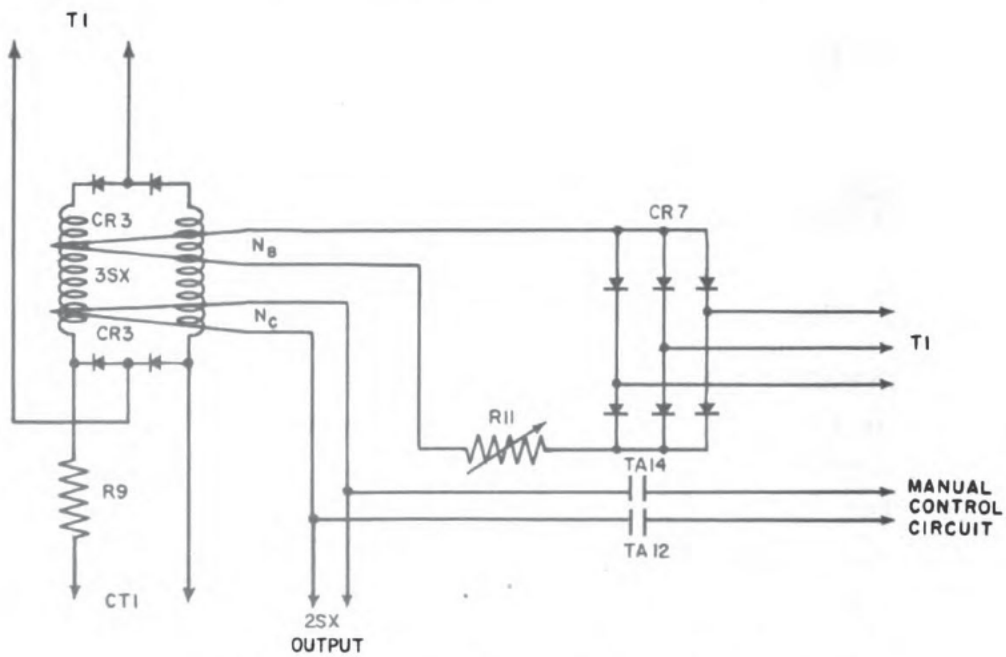


Figure 6—15.—Voltage-regulator magnetic-amplifier 3SX circuit.

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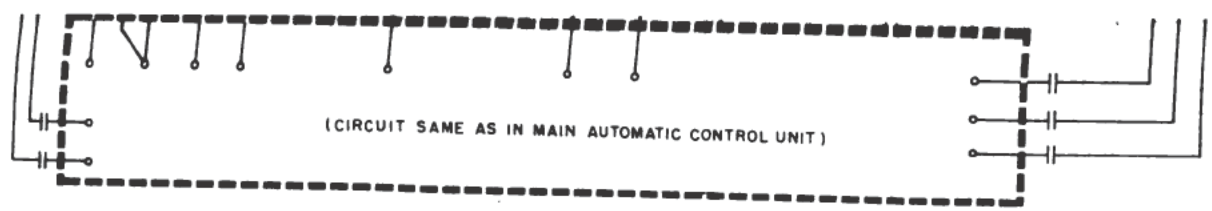


Figure 6–17.—Static excitation system and voltage regulation equipment schematic diagram.

(fig. 6–16) consists of switch 1*SW* and resistor *R*10. It is energized by the 40-kw d-c auxiliary generator. This circuit is required to furnish sufficient field current to start the a-c generator system. Switch 1*SW* is held momentarily in the START position until the a-c generator voltage builds up.

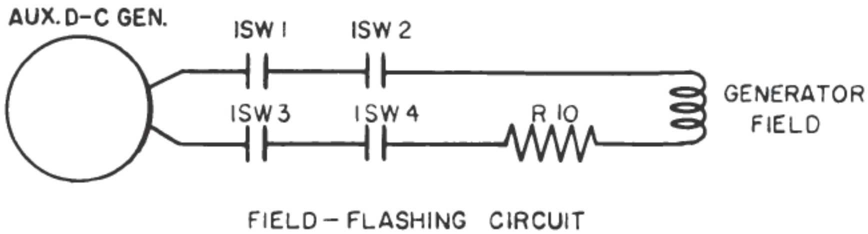


Figure 6—16.—Voltage-regulator field-flashing circuit.

After the a-c generator voltage has built up to the normal operating value, the auxiliary d-c generator is disconnected and is no longer needed for excitation purposes. The voltage regulator then maintains the bus voltage at the proper value for normal operation.

A schematic diagram of the complete static excitation system and voltage regulation equipment is indicated in figure 6–17. For initial operation and adjustment procedures refer to the instruction book furnished with the equipment.

SPEED REGULATION EQUIPMENT

Another application of magnetic amplifiers is found in a special type of motor-generator power supply for certain interior communications and fire-control equipments. Most ships have two of these motor generator sets. Usually the generators can be operated in parallel.

The sets provide a closely regulated 400-cycle output. Speed regulation is obtained by means of a magnetic-particle clutch between the motor and generator. Accessory control equipment functions to start the motor and to regulate the voltage and frequency of the a-c generator. Magnetic amplifiers are used in the voltage regulator and

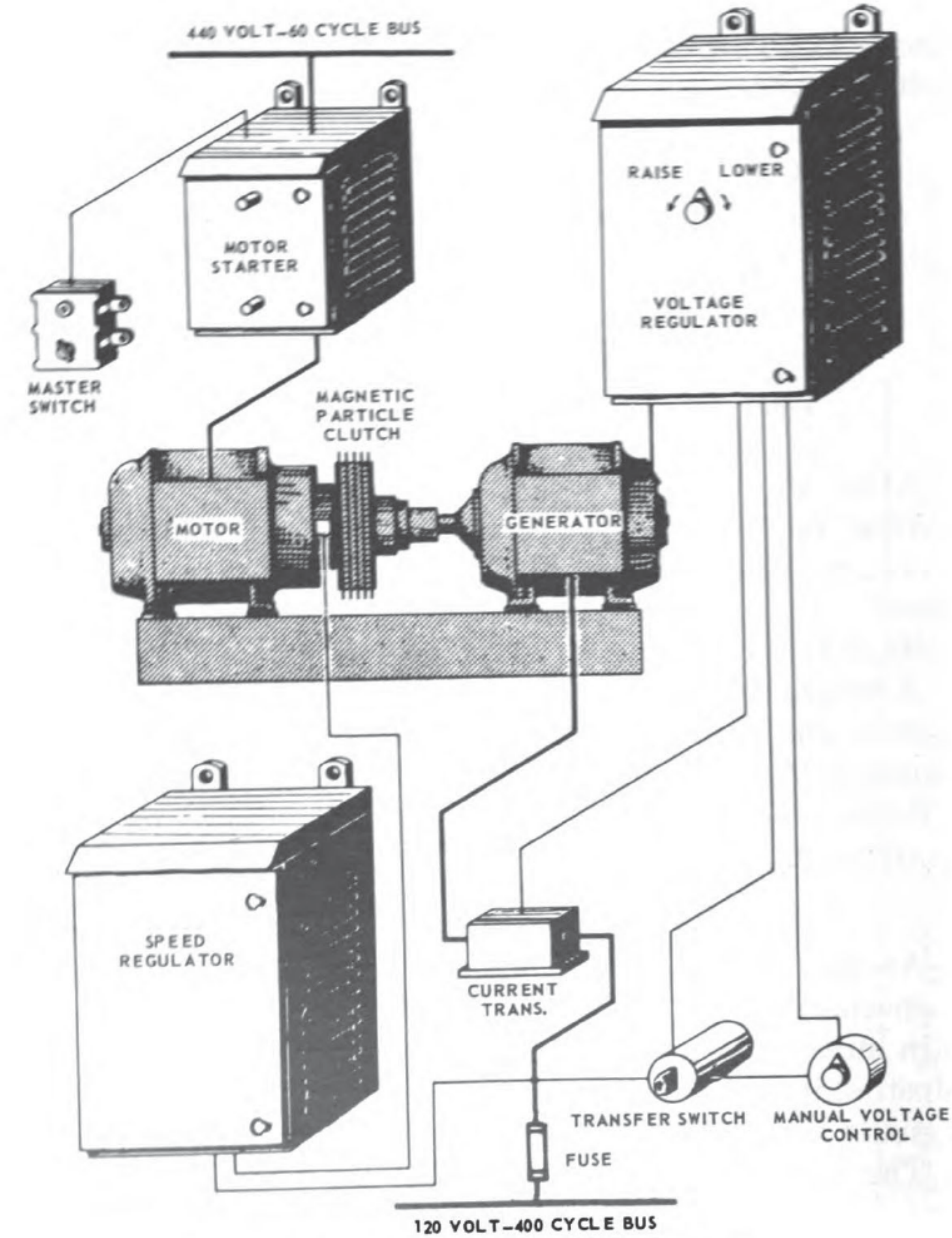


Figure 6—18.—Speed-regulation system block diagram.

also in the speed regulator. A block diagram of the speed-regulation system is indicated in figure 6–18.

Motor-Clutch Generator

The motor-clutch generator consists of an induction motor and an a-c generator that are mounted on a common bedplate. The shafts of the motor and generator are coupled by means of a magnetic-particle clutch.

MOTOR.—The motor is a 15-hp, 3-phase, 440-volt, 60-cycle induction motor that has a full-load speed of 3530 rpm at rated frequency. The speed of this motor changes with the load and the frequency of the power supply.

GENERATOR.—The generator is a 5-kw, 3-phase, 120-volt, 400-cycle synchronous generator that has a full-load speed of 3428 rpm. The rotor speed of this generator must be maintained very close to this value to provide a 400-cycle power output.

MAGNETIC-PARTICLE CLUTCH. — The magnetic-particle clutch (fig. 6–19) is the controllable coupling that transmits mechanical power from the motor to the generator. The difference between the changing motor speed and the required constant generator speed for 400 cycles is absorbed as controlled slip in the magnetic clutch.

The magnetic-particle clutch consists essentially of two independent rotating members; (1) the inner-driving member which is connected to the motor shaft and (2) the outer-driven member which is connected to the generator shaft. The working gap between these two members is partially filled with a mixture of iron particles and graphite.

The power is fed to the control coil through slip rings (not shown), and the resulting flux path is indicated by the broken line. The magnetic circuit includes the two halves of the inner member, the driven ring of the outer member, and the working gap, which contains the magnetic mixture.

The magnetic field, produced between the field yokes by

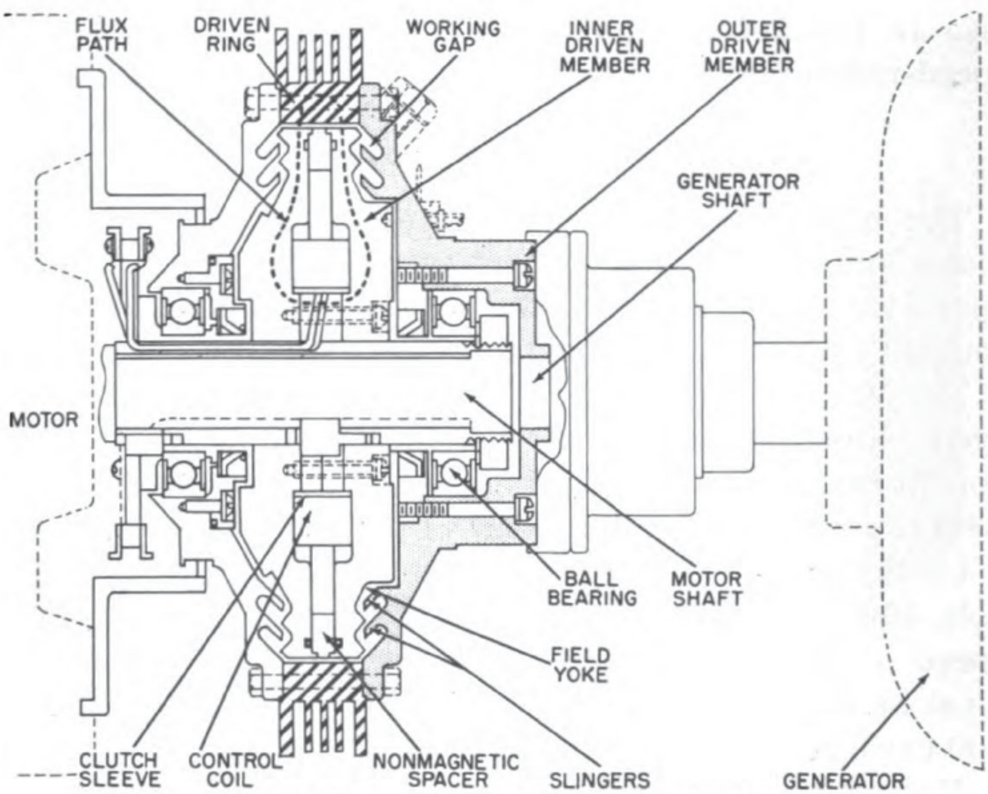


Figure 6—19.—Magnetic-particle clutch.

the current in the control coil, forms chains of iron particles that adhere to the two clutch members. The number and stiffness of these chains are determined by the strength of the magnetic field. The stronger the field the more nearly solid becomes the mixture.

The magnetic-particle clutch functions to control the difference between the motor and generator speeds. This speed difference appears as slip in the clutch. The slip and the speed of the outer-driven member can be regulated by varying the current in the control coil. The speed regulator, included in the accessory control equipment, automatically adjusts this clutch-coil current to control the output frequency of the a-c generator, which is coupled to the outer-driven member.

Accessory Control Equipment

The accessory control equipment includes (1) a motor controller, (2) a master switch, (3) an automatic-manual transfer switch, (4) a speed regulator, and (5) a voltage

regulator. When two complete speed-regulation systems are equipped for parallel operation (fig. 6–20), a parallel-operation relay and an automatic load-division assembly are included with the accessory control equipment.

MOTOR CONTROLLER.—The motor controller (fig. 6–20) includes a magnetically operated contactor, overload relays, and a pilot-circuit fuse. These components are mounted on a removable panel that is enclosed within a watertight case provided for bulkhead mounting. The speed-regulation system is operated by closing the master switch in the pilot circuit to energize the operating coil of the line contactor.

MASTER SWITCH.—The master switch (fig. 6–20) consists of two independent switches enclosed within a moisture-proof case provided for mounting on the switchboard. One switch marked STOP and START is a two-position rotary-type switch. The other switch, marked

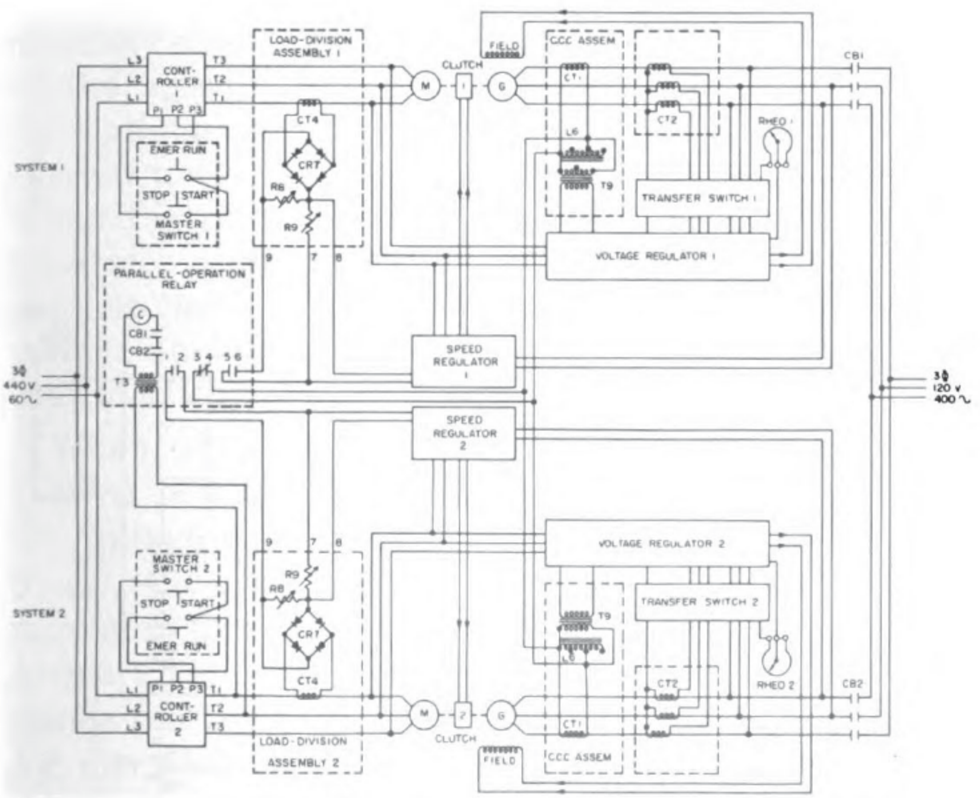


Figure 6—20.—Parallel operation of two speed-regulation systems.

EMERGENCY, is a normally open, single-spring return type of push switch that permits operation of the controller independently of the over-load protection.

AUTOMATIC MANUAL TRANSFER SWITCH.—The automatic-manual transfer switch (not shown) is an enclosed rotary switch mounted on the back of the switchboard with the operating handle projecting through the switchboard panel. It has four positions that function to interconnect the various voltage-regulator components that are necessary for the desired operation of the system. The OFF position deenergizes the voltage regulator; the START position energizes the control coil of the magnetic-particle clutch so that the generator attains speed; the MANUAL position provides manual control of the generator voltage; and the AUTOMATIC position provides complete automatic operation of the system.

SPEED REGULATOR, UTILIZING MAGNETIC AMPLIFIERS.—The speed regulator (fig. 6–21) controls the slip of the

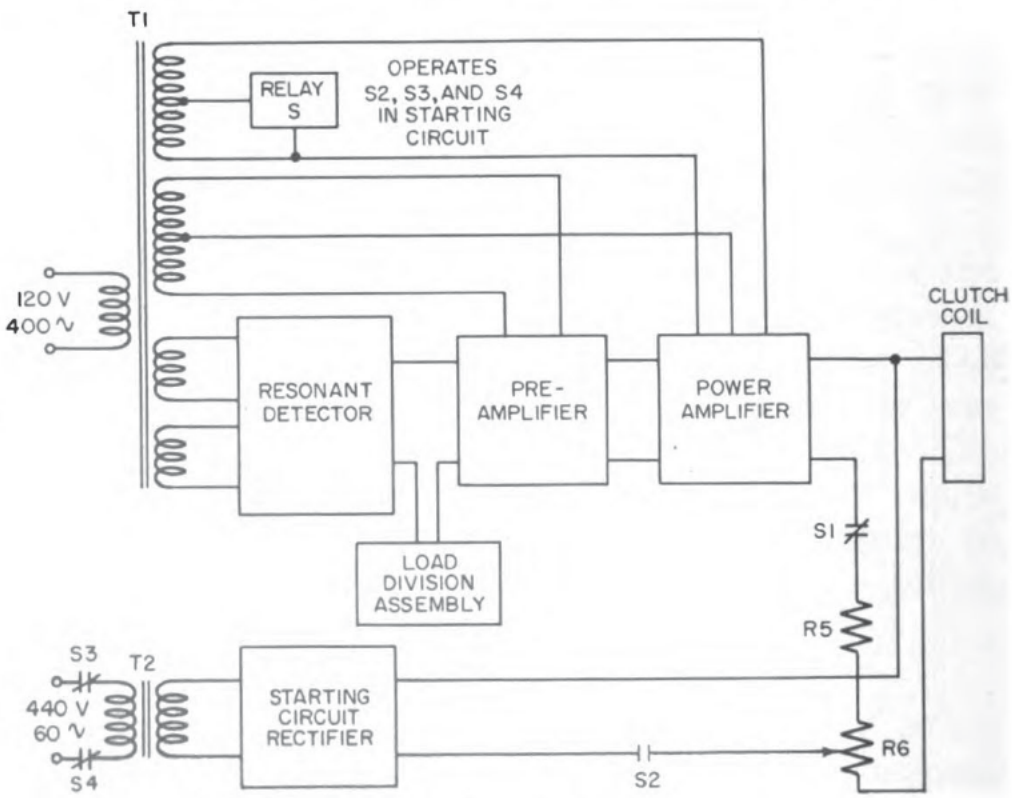


Figure 6—21.—Speed-regulator block diagram.

magnetic-particle clutch (under all load conditions) to regulate the frequency of the a-c generator output. It consists of a (1) starting circuit, (2) resonant-detector circuit, (3) preamplifier circuit, and (4) power-amplifier circuit. The preamplifier and power amplifier are magnetic amplifiers that employ high permeability cores.

The STARTING CIRCUIT (fig. 6–22) provides the initial excitation for the speed regulator. When the remotely located master switch is in the START position, the motor controller connects the a-c induction motor of the motor-clutch generator across the 3-phase, 440-volt, 60-cycle line (fig. 6–20). However upon starting the power supply, the a-c generator does not rotate, except possibly at a relatively low speed, because no excitation is immediately available to the magnetic-particle clutch due to the self-inductance of the control coil circuit. The single-phase, 440-volt, 60-cycle supply that is impressed across the speed regulator is applied to transformer T2 through normally closed relay contacts S3 and S4 because relay S in the speed regulator is deenergized. Rectifier CR5, through normally closed relay contact S2, supplies direct current to the control coil in the magnetic-particle clutch. When the control current builds up sufficiently, the a-c generator connected to the output shaft of the magnetic-particle clutch will rotate at motor speed because the d-c voltage applied to the clutch coil is of the proper magnitude to lock in the clutch.

When the automatic-manual transfer switch (not shown) is in the START position, excitation is supplied by the voltage regulator to the a-c generator field; a single-phase, 400-cycle voltage is impressed across the speed regulator through the primary of the main power transformer, T1, in the speed regulator. As the value of the impressed voltage approaches 120 volts, the speed-regulator circuits, supplied by the secondaries of transformer T1, are energized. Relay S operates to close contact S1 and to open the normally closed contacts, S2, S3, and S4

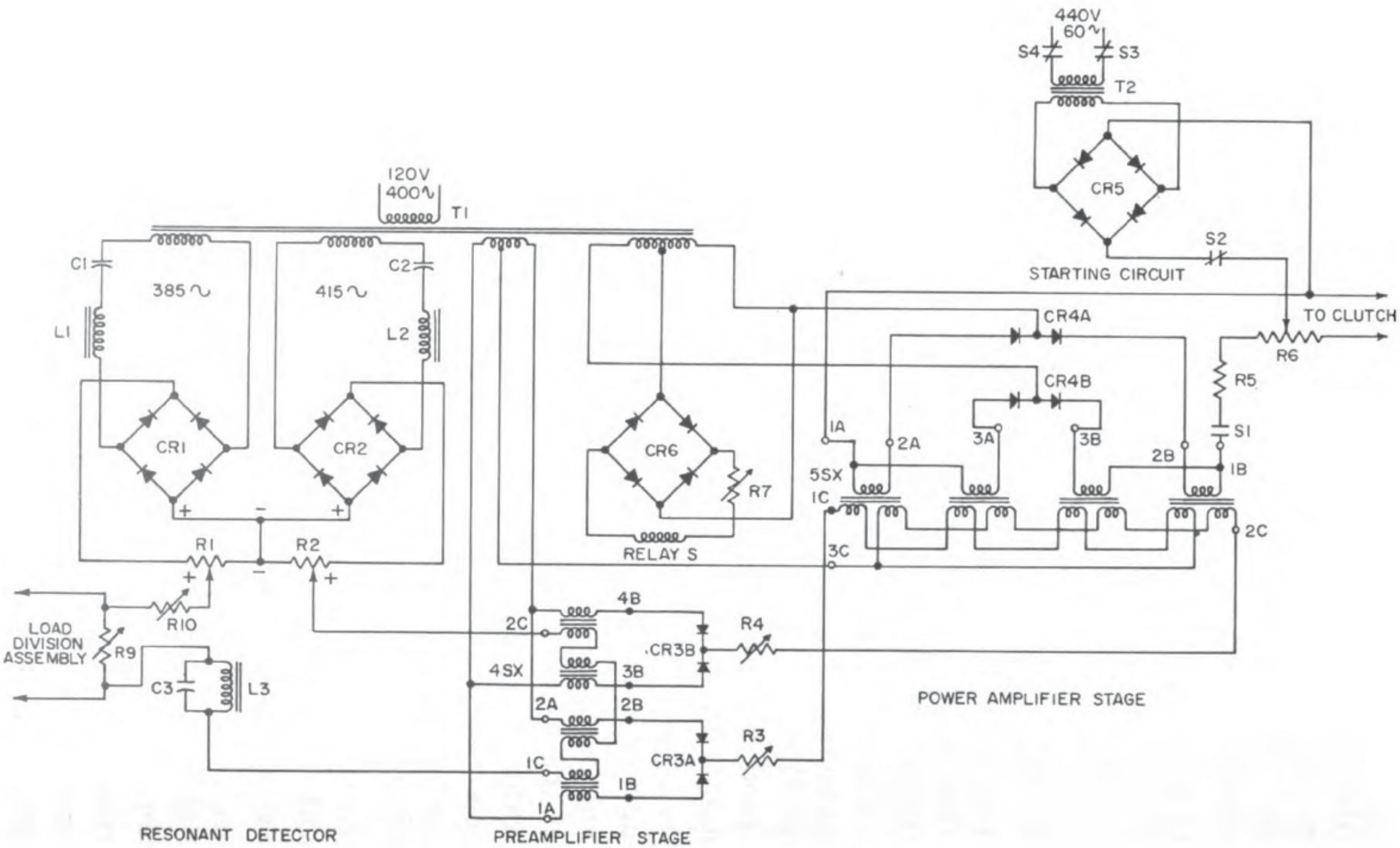


Figure 6—22.—Speed-regulator starting circuit.

(fig. 6–21). This action disconnects the 60-cycle excitation supply from the starting circuit in the speed regulator, and it supplies current to the magnetic-particle clutch from rectifier CR5 through the speed regulator.

The RESONANT DETECTOR CIRCUIT consists of the full-wave bridge rectifiers, *CR*1 and *CR*2, supplied from transformer T1 through separate series resonant circuits that consist of *C*1–*L*1 and *C*2–*L*2, respectively.

The purpose of the *L–C* networks is to automatically maintain the output of the 400-cycle, m-g set at approximately a 400~ frequency (385 to 415~). This action is accomplished by the two *L–C* networks, establishing low and high limits on any variation of the 400~ output that might occur, as follows.

The series resonant circuit, C1–L1, is in series with a secondary of transformer *T*1 through rectifier *CR*1. When the frequency of the a-c generator output voltage applied to the speed regulator is approximately 385 cycles, the impedance of this resonant circuit is nearly zero; that is, *C*1 and *L*1 are in series resonance, and most of the voltage supplied by the secondary of *T*1 is applied to rectifier CR1 and potentiometer *R*1. Thus, the direct current from *CR*1 is relatively high, and the voltage across potentiometer *R*1 is also high. If the frequency of the applied voltage to the speed regulator deviates from 385 cycles, the impedance of this resonant circuit increases very rapidly, and most of the voltage supplied by the secondary of *T*1 is dropped across this impedance. This action reduces the voltage supplied to *CR*1 and *R*1, thereby reducing the d-c output voltage.

The resonant circuit consisting of *C*2 and *L*2 is in series with a secondary of transformer T1 through rectifier *CR*2. When the frequency of the a-c generator output voltage that is applied to the speed regulator is approximately 415 cycles, the impedance of this resonant circuit is nearly zero; that is, *C*2 and *L*2 are in series resonance, and most of the voltage supplied by the secondary of *T*1

is applied to rectifier $CR2$ and resistor $R2$. Thus, the direct current from $CR2$ is relatively high, and the voltage across potentiometer $R2$ is also high. If the frequency of the applied voltage deviates from 415 cycles, the impedance of this resonant circuit increases very rapidly, and most of the voltage supplied by the secondary of $T1$ is dropped across this impedance. This action reduces the voltage supplied to $CR2$ and $R2$, thereby reducing the d-c output voltage.

The resultant d-c output voltage of $CR1$ and $CR2$ across potentiometers $R1$ and $R2$ is fed to the control winding, $1C$–$2C$, of reactor $4SX$ in the preamplifier stage of the regulator through an 800-cycle second-harmonic wave-trap that is comprised of capacitor $C3$ and inductor $L3$. These units are parallel resonant at 800 cycles and so remove any 800-cycle frequency component from the output to the preamplifier stage by presenting a high series impedance at this frequency.

The output of the resonant detector circuit, fed to the preamplifier stage, is a reversible direct current determined by the frequency of the a-c generator output voltage applied to the regulator. If the frequency of the applied voltage is near 385 cycles, more current flows in $R1$ than in $R2$, and terminal 1C will be positive with respect to terminal $2C$. Conversely, if the frequency of the applied voltage is near 415 cycles, more current flows in $R2$ than in $R1$, and the polarity of the output signal, fed to the preamplifier stage, is reversed.

Thus, the resonant detector circuit changes frequency variations of the applied input voltage into polarity variations of the output voltage, which are fed to the preamplifier stage. Polarity depends on frequency, and when the frequency of the applied input voltage is 400 cycles, both halves of the resonant detector circuit are balanced, and the value of the resultant output voltage is practically zero.

When the frequency of the voltage that is applied to the speed regulator is less than 400 cycles, the impedance

of the resonant circuit, comprising $C1$ and $L1$, decreases as the value of the generator output deviates above its series resonance of 385 cycles. This action allows more current to flow from the secondary of $T1$ through $CR1$ and $R1$. Simultaneously, the impedance of the resonant circuit, comprising $C2$ and $L2$, increases as the value of the generator output deviates below its series resonance of 415 cycles. This action reduces the flow of current from the secondary winding of $T1$ through $CR2$ and $R2$, making terminal $1C$ more positive with respect to terminal $2C$.

The PREAMPLIFIER CIRCUIT (fig. 6–22), the principal component of which is the saturable reactor, $4SX$, has two output circuits. Each output circuit comprises two load windings. One output circuit supplies rectifier $CR3A$ through load winding terminals $1B$ and $2B$. The other output circuit supplies rectifier $CR3B$ through load winding terminals $3B$ and $4B$. The signal from the resonant detector circuit is fed to terminals $1C$ and $2C$ of the control windings.

The control windings are so wound on the cores that they produce opposite effects on the two output circuits. When terminal $1C$ of $4SX$ is positive with respect to terminal $2C$, the cores of load windings $1A$–$1B$ and $2A$–$2B$ become saturated. The impedance of these windings decreases and most of the voltage from the secondary of $T1$ is available for the load. This action results in an increase in current to $CR3A$ and $R3$. Simultaneously, the cores of load windings $1A$–$3B$ and $2A$–$4B$ becomes desaturated. The impedance of the windings increases, and most of the voltage applied to terminals $1A$ and $2A$ of $4SX$ from the secondary of $T1$ is dropped across these load windings. Hence, little of the supply voltage is available for the load. This action results in a decrease in current to $CR3B$ and $R4$.

Conversely, when terminal $2C$ is positive with respect to terminal $1C$, the reverse action occurs and more current flows in $R4$ than in $R3$. When the potential between

terminals $1C$ and $2C$ is zero, which occurs when the frequency of the generator output is 400 cycles, equal currents flow in resistors $R3$ and $R4$.

Therefore, reactor $4SX$ converts voltage-polarity changes into current variations in the output of the preamplifier stage. This d-c output current is fed from terminals $1C$ and $2C$ to the separate control windings, $1C$–$3C$ and $2C$–$3C$, of the reactor, $5SX$, in the power amplifier stage.

The POWER AMPLIFIER CIRCUIT (fig. 6–22) has as its principal component, saturable reactor $5SX$. The output of $5SX$ is fed to the control coil of the magnetic-particle clutch through reactor terminals $1A$ and $1B$ of the power amplifier stage.

The signal current from the preamplifier stage is fed to terminals $1C$ and $2C$ of reactor $5SX$. The two control windings $1C$–$3C$ and $2C$–$3C$ of $5SX$ are wound on the cores so that they produce opposite effects on the load windings. The current in control winding $1C$–$3C$ tends to saturate reactor $5SX$, whereas the current in control winding $2C$–$3C$ tends to desaturate reactor $5SX$. The net effect of the two control windings provides the control current for $5SX$, the output of which controls the amount of current supplied to the magnetic-particle clutch. When the magnitude of the d-c signal in control winding $1C$–$3C$ is greater than that of the d-c signal in control winding $2C$–$3C$, reactor $5SX$ becomes saturated and its impedance decreases. Thus, most of the voltage supplied to $5SX$ by the secondary winding of $T1$ is available for the load which is the control coil of the magnetic-particle clutch.

Conversely, when the magnitude of the d-c signal in the control winding, $2C$–$3C$, is greater than that of the d-c signal in the control winding, $1C$–$3C$, reactor $5SX$ becomes desaturated and its impedance increases. Thus, most of the voltage supplied to $5SX$ by the secondary winding of $T1$ is dropped across the load windings of $5SX$, and little voltage is available for the control coil of the magnetic-particle clutch.

When a decrease in the frequency of the input voltage occurs across the primary of transformer $T1$ in the speed regulator, the resonant detector circuit feeds a signal to the preamplifier stage, which supplies more current to control winding $1C$–$3C$ than is supplied to control winding $2C$–$3C$ of the power amplifier stage, $5SX$. This action tends to saturate $5SX$, thereby permitting an increase in current to flow through reactor load winding terminals $1A$ and $1B$ to the control coil of the magnetic-particle clutch. This increase in current to the control coil reduces the slip of the magnetic-particle clutch and the generator speeds up, thereby increasing the frequency of the generator output. When the generator speed returns to normal, the speed-regulator circuits automatically readjust to produce the reverse action until the frequency is stabilized at 400 cycles.

PARALLEL-OPERATION RELAY.—The parallel-operation relay (fig. 6–20) consists of a relay and transformer $T3$ that are enclosed within a drip-proof case provided for bulkhead mounting. The relay is of the magnetic spring-loaded type with two normally open and one normally closed contacts. When both generator breakers are closed, the relay is energized through transformer $T3$ from the 440-volt, 60-cycle bus through auxiliary contacts $CB1$ and $CB2$ on each generator circuit breaker. The transformer supplies 115 volts to the relay.

This action interconnects the load division assemblies through relay contacts 1–2 and 5–6. At the same time relay contacts 3–4 open the short circuit across the cross-current compensation assemblies and proper control of excitation is assumed. If either of the speed regulation systems is shut down, the parallel-operation relay is automatically disconnected by the circuit-breaker auxiliary contacts, $CB1$ or $CB2$, to disconnect the parallel-operation components.

AUTOMATIC LOAD-DIVISION ASSEMBLY.—The function of the load division assembly is to maintain equal load on

each 400-cycle power supply system for parallel operation of two systems. The automatic load-division assembly (fig. 6–20) consists of resistors *R*8 and *R*9, full-wave rectifier *CR*7, and current transformer *CT*4. Transformer *CT*4 is inserted in series with one phase of the 3-phase, 440-volt, 60-cycle input to the a-c motor. These components are enclosed within a drip-proof case mounted on the a-c motor frame.

Current transformer *CT*4 of the load-division assembly (fig. 6–23) supplies a voltage proportional to the motor current to rectifier *CR*7. The d-c output signal of

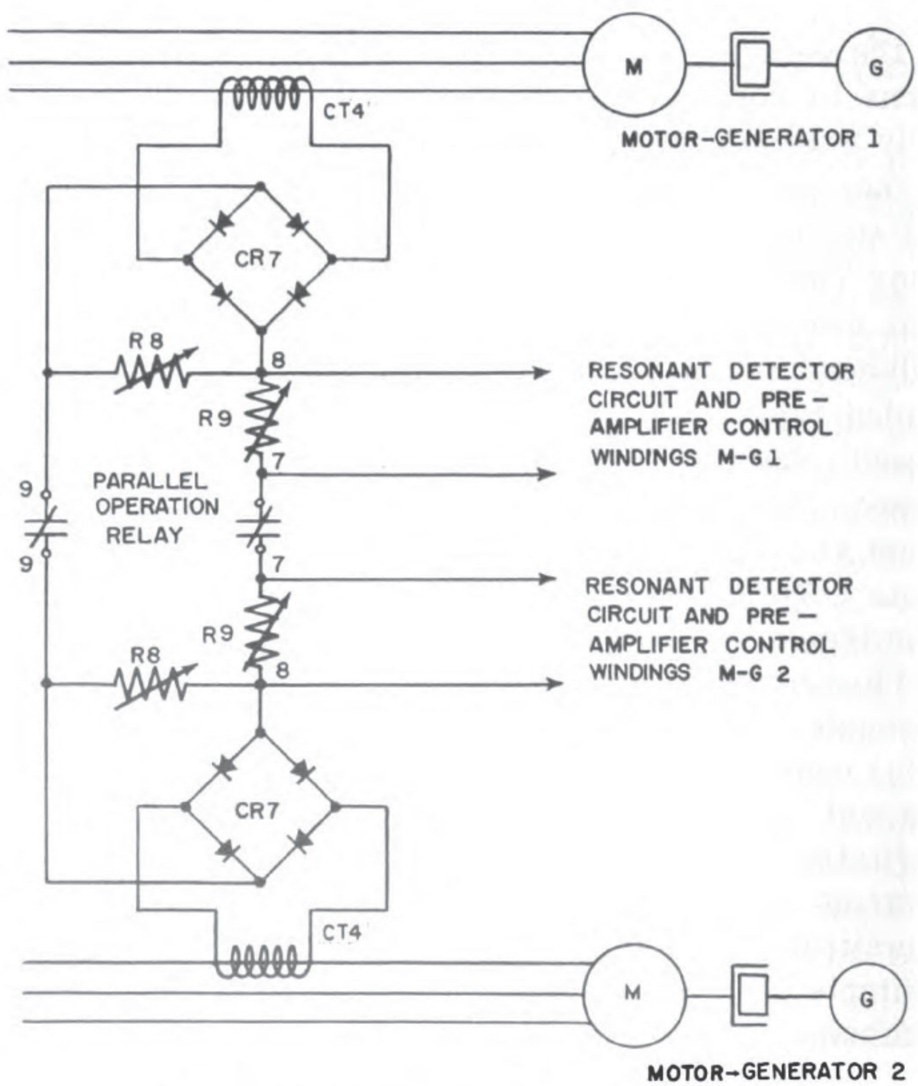


Figure 6–23.—Load-division assemblies.

*CR*7 is fed to resistors *R*8, one being located in each load-division assembly. These two d-c signals are connected in opposition through terminals 7 and 9 in each load-division assembly and the relay contacts in the parallel-operation relay. When the two motor currents are equal, the opposing d-c voltages cancel each other; no effect is produced. On the other hand, when one generator tends to carry more than half the load, a circulating current flows through resistors *R*9, one being located in each load-division assembly. This action results in a voltage drop across resistors *R*9, which is inserted between terminals 7 and 8 in each load-division assembly. This voltage is of reversible polarity. It always makes terminal 8 positive with respect to terminal 7 on the more heavily loaded generator and vice versa on the more lightly loaded generator.

The output of the resonant detector circuit (fig. 6–22) must flow through resistor *R*9 in the load-division assembly before it is fed to the control winding of reactor 4*SX* in the preamplifier stage. Hence, resistor *R*9 is common to both the resonant detector circuit and the load-division assembly and there are two voltages of reversible polarity in series supplying the control windings, 1*C*–2*C*, of reactor 4*SX* (fig. 6–23). One voltage, derived from a resonant detector circuit through resistors *R*1 and *R*2, develops from a change in the frequency of the input voltage applied to the speed regulator (fig. 6–20). The other voltage, derived from resistor *R*9 in the load-division assembly, develops from the unequal load division between the generators and is applied to the speed regulators. A change in either of these voltages has the same effect on the preamplifier-stage output and acts to change the value of the voltage supplied to the control coil of the magnetic-particle clutch. Hence, the signal fed to the speed regulators results in decreased clutch excitation to the system with the higher motor current and increased clutch excitation to the system with the lower motor current.

Under single-system operation the load-division circuit is not connected into the regulating system and the secondaries of the current transformers supplying the cross-current compensation assemblies are shorted by contacts 3–4 of the parallel operation relay (fig. 6–20).

VOLTAGE REGULATOR, UTILIZING MAGNETIC AMPLIFIERS.—The voltage regulator supplies the d-c excitation for the generator field. The block diagram (fig. 6–24) includes the voltage regulator. It consists essentially of three components; (1) voltage detector, (2) preamplifier, and (3) power amplifier. The detector is sensitive to generator voltage changes and supplies a signal proportional to these generator voltage changes to the preamplifier. The signal is amplified and supplied to the power amplifier. The power amplifier controls the excitation current to the

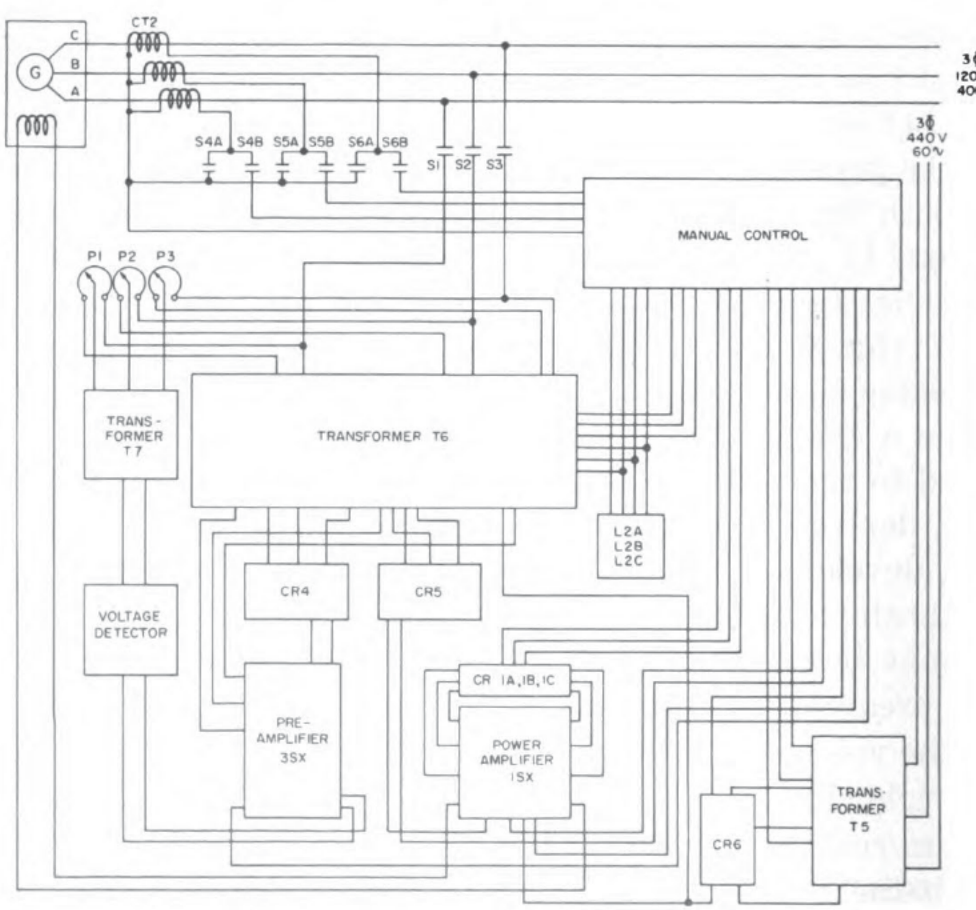


Figure 6—24.—Block diagram of voltage regulator.

generator field. Provisions are made for manual and automatic control of the voltage regulator. Current transformers *CT*2 provide additional excitation that is proportional to the load current.

The STARTING CIRCUIT (fig. 6–25) provides the initial field excitation for the generator. When the remotely located master switch is operated to its START position, the motor controller functions to connect the a-c induction

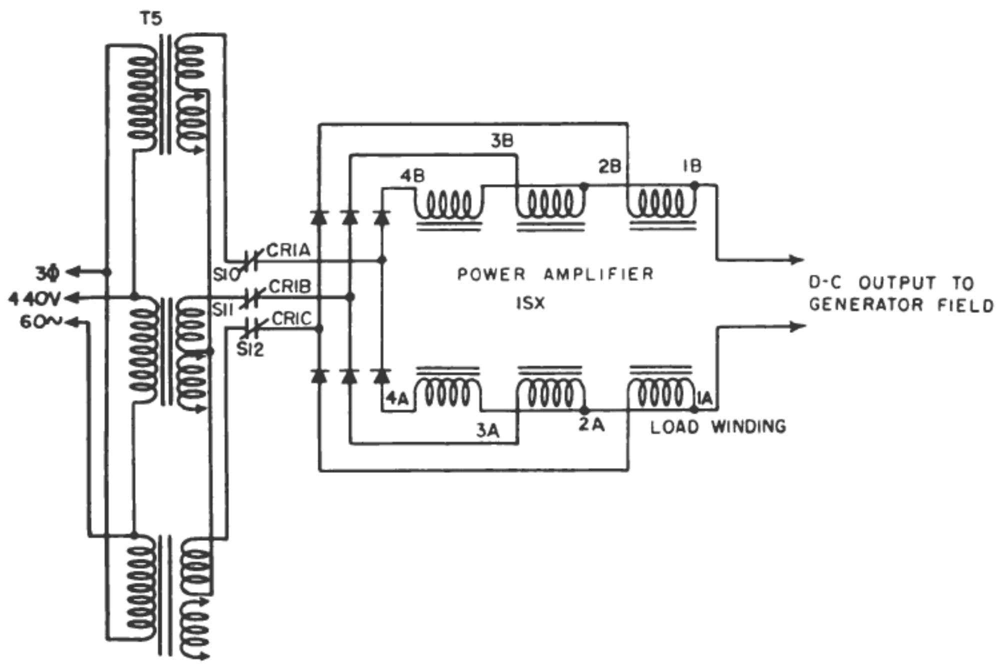


Figure 6—25.—Voltage-regulator starting circuit.

motor of the motor-clutch generator across the 3-phase, 440-volt, 60-cycle source (fig. 6–20). The a-c generator output voltage does not build up at this time because no excitation is available to the generator field.

When the automatic-manual transfer switch (not shown) is operated to its START position, the primaries of transformer *T*5 (fig. 6–25) within the voltage regulator are connected to the 3-phase, 440-volt, 60-cycle bus. The wye-connected secondaries of transformer *T*5 energize rectifiers *CR*1*A*, *CR*1*B*, and *CR*1*C* in the power amplifier stage of the voltage regulator through switch contacts

$S10$, $S11$, and $S12$. The impedance of reactor $1SX$ at 60 cycles is sufficiently low to pass no-load direct current to the a-c generator field through reactor terminals $1A$ and $1B$; the a-c generator output voltage builds up. The bias and control windings of $1SX$ are not used during the period of initial excitation.

The MANUAL VOLTAGE CONTROL CIRCUIT (fig. 6–26) provides manual control of the a-c generator output voltage over a relatively wide range by means of the manual voltage control rheostat, Rheo. 1. This circuit is intended for emergency use only.

When the automatic-manual transfer switch (not shown) is in the MANUAL position, the manual-voltage-control rheostat, Rheo. 1, mounted on the switchboard, is connected into the voltage-regulator circuit.

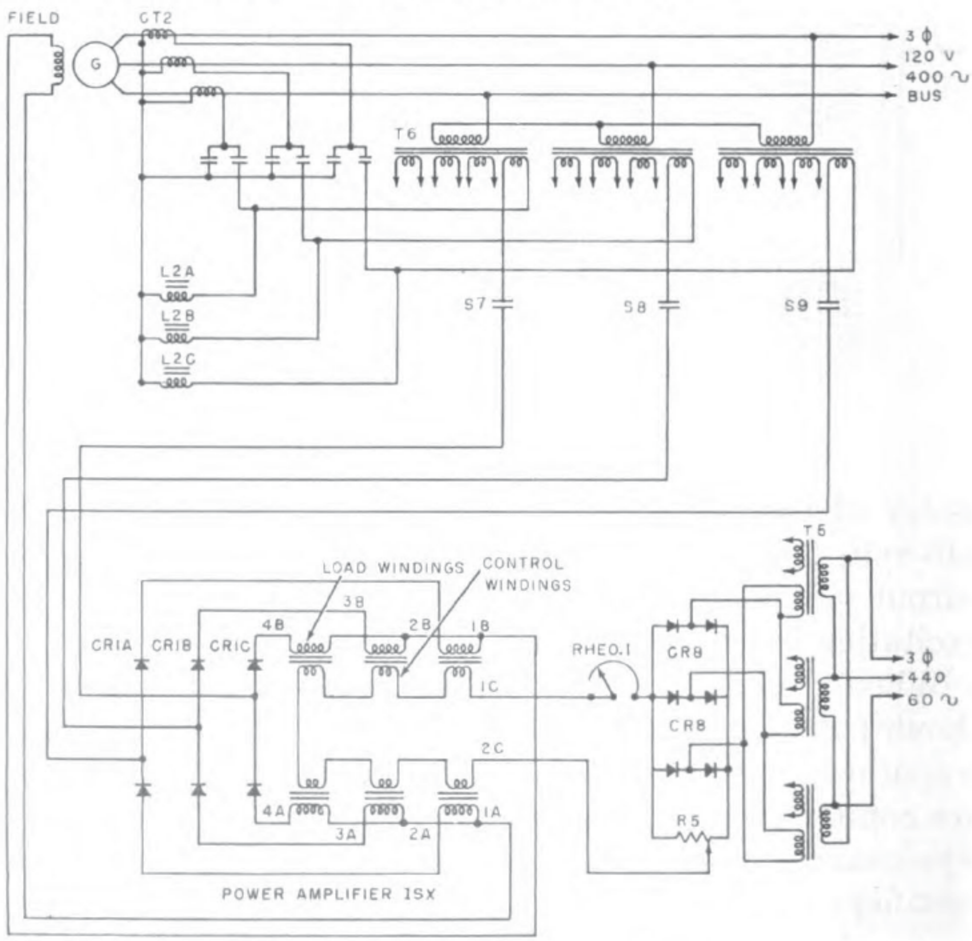


Figure 6—26.—Voltage-regulator manual-voltage control circuit.

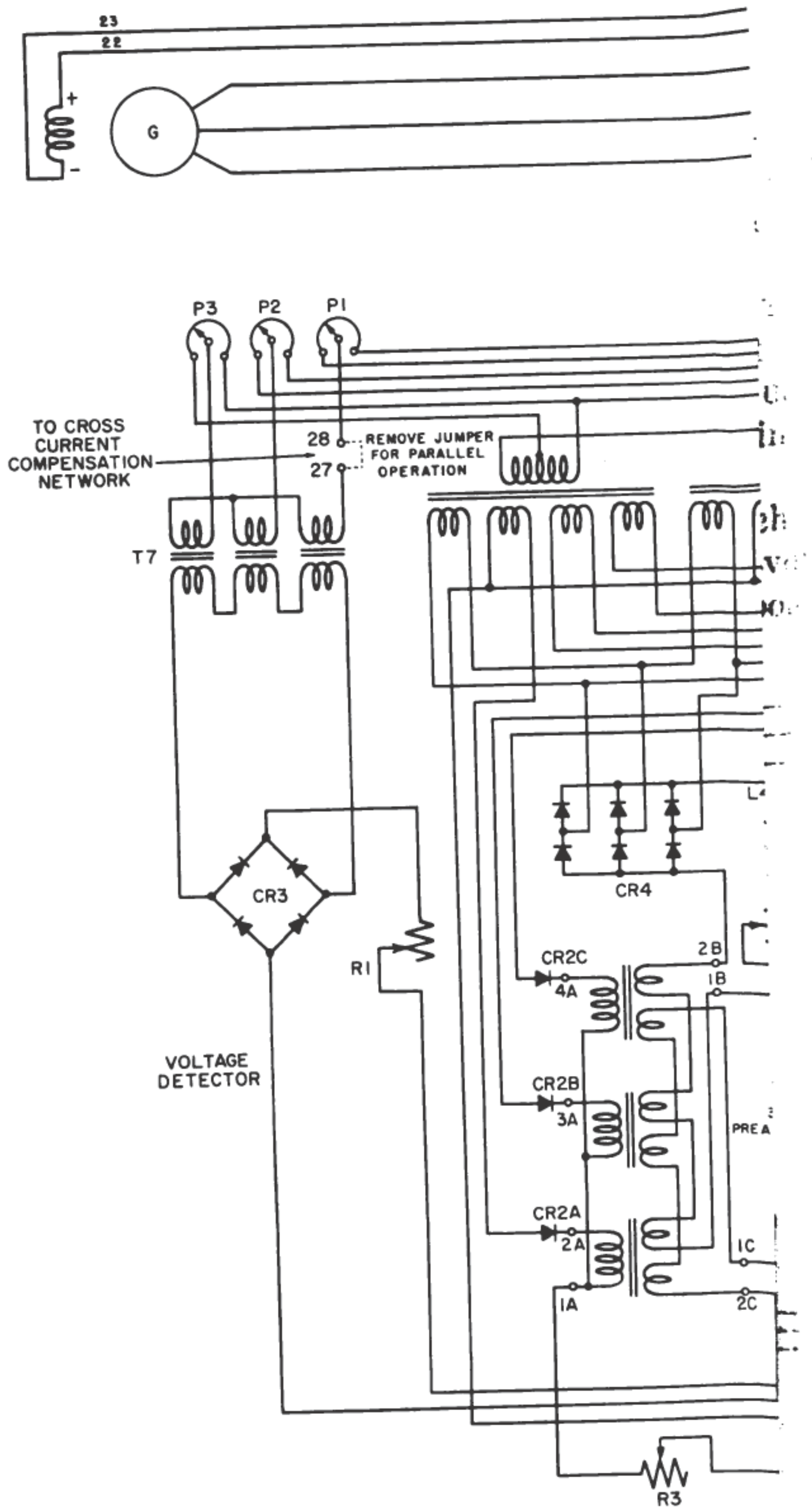


Figure 6–27.—Voltage-regulat

The generator field now derives its power from its own armature. The path includes the wye-connected secondaries of transformer $T6$; the load windings of power amplifier $1SX$; rectifiers $CR1A$, $CR1B$, and $CR1C$; inductors $L2A$, $L2B$, and $L2C$; and switch contacts 7, 8, and 9. Under conditions of manual control, power for the control winding, $1C$–$2C$, of the power amplifier, power for the control winding, $1C$–$2C$, of the power amplifier, $1SX$, is obtained from the delta-connected secondaries of transformer $T5$, which is energized from the 440-volt, 60-cycle bus. The current for the control windings, $1C$–$2C$, of the power amplifier, $1SX$, is regulated by the manual-voltage-control rheostat, Rheo. 2, and is in a direction that tends to saturate the core of power amplifier $1SX$ (opposite to that under automatic control). For example, increasing the amount of control current to winding $1C$–$2C$ will saturate $1SX$, thereby causing a decrease in the impedance of the six load windings and making available for the generator field most of the rectified supply voltage from transformer $T6$. This d-c output voltage is supplied to the generator field through power amplifier terminals $1A$ and $1B$, thereby increasing the field current and generator output voltage.

Conversely, a decrease in the current in control winding $1C$–$2C$ desaturates reactor $1SX$, causing a corresponding increase in the impedance of the load windings. Thus, most of the supply voltage is expended across the reactance of the load windings of $1SX$, resulting in a decrease in the generator output voltage. The bias winding of amplifier $1SX$ is not used under manual-control conditions.

When the transfer switch (fig. 6–20) is in the automatic position, the voltage regulator automatically regulates the generator output voltage. Automatic control utilizes the voltage detector, preamplifier, and power amplifier, as illustrated in the schematic circuits of figure 6–27.

The VOLTAGE DETECTOR CIRCUIT (fig. 6–27) consists of a full-wave bridge rectifier *CR*3, supplied from the delta-connected secondaries of transformer *T*7. Rectifier *CR*3 is inserted within the closed loop formed by the delta-connected secondaries of *T*7. The fundamental frequency components of the secondary voltage are cancelled within the loop, but the third harmonic voltages of each generator phase are additive and are rectified to produce a single d-c control current. When transformer *T*7 is operated at the proper flux value, its sensitivity is high, the rectified current versus input voltage is very steep, and the output current changes many times as rapidly as the input voltage.

Transformer *T*7 is supplied from potentiometers *P*1, *P*2, and *P*3. Each potentiometer is connected across a portion of the primary windings of *T*6. The adjustable contacts are activated by a common control shaft and thus provide simultaneous and equal adjustment of the three sections of the potentiometers. The adjustment of *P*1, *P*2, and *P*3 controls the relationship between the a-c generator bus voltage, which energizes *T*6 and the detector voltage, which is derived from the output of *T*7. For example, when *P*1, *P*2, and *P*3 are adjusted so that the voltage to *T*7 is increased, the d-c control current, derived from the voltage-detector circuit across *CR*3, increases rapidly. The voltage regulator acts as if the bus voltage were high and automatically reduces the excitation supplied to the generator field. The bus voltage will then drop. Conversely when *P*1, *P*2, and *P*3 are adjusted so that a smaller portion of the generator output is applied to the detector, the regulator acts as if the bus voltage were low, the excitation supplied to the generator field is increased, and the bus voltage will rise.

Hence, the regulated-voltage control potentiometers, *P*1, *P*2, and *P*3, control the portion of the voltage that is applied to the voltage regulator and may therefore be used

to set the level at which the generator output voltage is regulated.

The voltage-detector circuit functions to detect changes in the supply voltage applied to transformer T6 and to transmit these changes in the form of a d-c signal to the voltage-regulator preamplifier stage. When the input voltage to *T*6 is high, the voltage-detector output is high; when the input voltage to *T*6 is low, the voltage-detector output is low. The d-c output of the voltage-detector circuit is fed to the control winding, 1*C*–2*C*, of the preamplifier stage, 3*SX*.

The PREAMPLIFIER CIRCUIT (fig. 6–27) consists essentially of the magnetic amplifier reactor, 3*SX*, with bias winding 1*B*–2*B* and control winding 1*C*–2*C*, connected in opposition. The bias current in winding 1*B*–2*B* tends to desaturate the core of 3*SX*, whereas the control current in winding 1*C*–2*C* is in the saturating direction. Hence, the output of 3*SX* is directly proportional to the control current derived from the voltage-detector circuit.

The preamplifier stage of the voltage regulator amplifies the d-c signal from the detector and applies this amplified signal in the form of a direct current to the regulator power amplifier stage. When the detector signal that is applied to the control winding of 3*SX* is small because of low bus voltage, the bias mmf desaturates the core of 3*SX* and thus increases the impedance of the load windings. Hence, a large portion of the voltage from *T*6 supplied through rectifiers *CR*2*A*, *CR*2*B*, and *CR*2*C* is expended as voltage drop across the load windings of 3*SX*, and little voltage is available for the load.

On the other hand, when the detector signal applied to the control winding is large because of high bus voltage, the control mmf counteracts the bias mmf, and the core of 3*SX* becomes saturated, thereby decreasing the impedance of the load windings. Hence, most of the voltage from transformer *T*6 that is supplied through rectifiers *CR*2*A*, *B*, and *C* is available for the load. The d-c output

of the preamplifier stage is fed to the control winding, 1*C*–2*C*, of the power amplifier, 1*SX*, of the voltage regulator.

The POWER-AMPLIFIER CIRCUIT (fig. 6–27) consists principally of saturable reactor 1*SX* with bias winding 3*C*–4*C* and control winding 1*C*–2*C* connected in opposition. The bias current in winding 3*C*–4*C* tends to saturate 1*SX*, whereas the control current in winding 1*C*–2*C* is in the desaturating direction. Hence, the output of 1*SX* is inversely proportional to the control current derived from the preamplifier stage.

The power-amplifier stage of the voltage regulator controls the generator-field current. When the preamplifier signal that is applied to the control winding is low because of low bus voltage applied to the speed regulator, the bias flux saturates the core of 1*SX*, and thus decreases the impedance. Hence, most of the voltage supplied to 1*SX* from transformer *T*6 and inductors *L*2*A*, *L*2*B*, and *L*2*C* is available for the load.

On the other hand, when the preamplifier signal, applied to the control winding, is high because of high bus voltage applied to the speed regulator, the control flux counteracts the bias flux and desaturates the core of 1*SX*, thereby increasing the impedance. Hence, most of the voltage to 1*SX* from transformer *T*6 and inductors *L*2*A*, *L*2*B*, and *L*2*C* is expended as voltage drop across reactor 1*SX*, and little voltage is available for the generator field, which is connected to terminals 1*A* and 1*B* of reactor 1*SX*.

Figure 6–27 illustrates that portion of the voltage-regulator automatic-control circuit that has been discussed thus far; that is, the voltage-detector circuit, the preamplifier stage, and the power-amplifier stage. The signal amplification that would be caused in this combined circuit by a decrease in the bus voltage is as follows; (1) the control current input from the preamplifier stage to control winding 1*C*–2*C* of power amplifier 1*SX* decreases; (2) the core flux of 1*SX* increases because the saturating-

bias mmf is opposed by less desaturating-control mmf; (3) the impedance of the load windings of 1SX decreases, and the direct current output to the generator field increases. This action increases the generated voltage, thereby checking the decrease in terminal voltage.

Conversely, if the generator output voltage increases, the following action will occur; (1) the control-current input from the preamplifier stage to control winding 1C–2C of power amplifier 1SX increases; (2) the core flux of 1SX decreases because the saturating-bias mmf is opposed by more desaturating-control mmf; (3) the impedance of the load windings of 1SX increases, and the direct current output to the generator field decreases. This action decreases the generated voltage, thereby checking the increase in terminal voltage.

Current transformers CT2 function to maintain a steady terminal voltage with load change. As mentioned before, they provide an additional excitation signal to the generator field that is proportional to the generator load currents. For example, the voltage developed across inductor $L2A$ is proportional to the current in phase A of the generator bus. This voltage is additive with respect to the voltage of phase A, developed by potential transformer T6 that supplies the load winding of phase A of the power amplifier, 1SX. Thus, when the generator load current increases, the field excitation current through the load windings of 1SX will increase. This action tends to stabilize the terminal voltage by increasing the generated voltage with increase in armature current and internal armature impedance voltage drop.

CROSS-CURRENT-COMPENSATION ASSEMBLY.—The cross-current-compensation assembly (fig. 6–20) consists of transformers CT1 and T9, and inductor L6 that are enclosed within a drip-proof case mounted on the a-c generator frame.

The cross-current-compensation assembly is used when two speed-regulation systems are operated in parallel to eliminate circulating cross currents between the two sys-

tems. One assembly is used for each of the two systems. A schematic diagram of the cross-current-compensation circuits is illustrated in figure 6–28. Current transformers *CT*1 are energized from phase C of the generator bus. Inductors *L*6 are connected across the secondaries of the current transformers to provide a low impedance path for the secondary current. The voltage drop across the inductors is applied to the primaries of transformers *T*9. The secondaries of *T*9 are connected between terminals 27 and 28 of phase C of the primaries of transformer *T*7 in the voltage detector circuit (fig. 6–27). Under single-system operation, a strap is connected between terminals 27 and 28, thereby shorting out transformer *T*9. Satisfactory single-system operation is obtained because only one generator is connected to the load bus, and the load-division circuit is not connected into the regulating system.

Before parallel operation is effected, the straps are removed from terminals 27 and 28 of the voltage detector, thereby inserting the secondary of transformer *T*9 of the cross-current compensation assembly in series with the primary of phase C of transformer *T*7 of the voltage detector circuit (fig. 6–27).

When the second generator is connected to the load bus by closing its circuit breaker, the circuit between the secondary of transformer *T*3 (fig. 6–20) and the parallel-operation relay coil, *C*, is completed through the auxiliary contacts, *CB*1 and *CB*2, of the two circuit breakers. When the parallel-operation relay coil is energized, the relay armature is activated and closes the two normally open contacts and opens the normally closed contact. The opening of the normally closed relay contact, POR, removes the shorting connection effected through the parallel-operation relay assembly (fig. 6–28) and connects together the two speed-regulation systems of each of the two cross-current-compensation assemblies.

Without cross-current compensation, improper field ex-

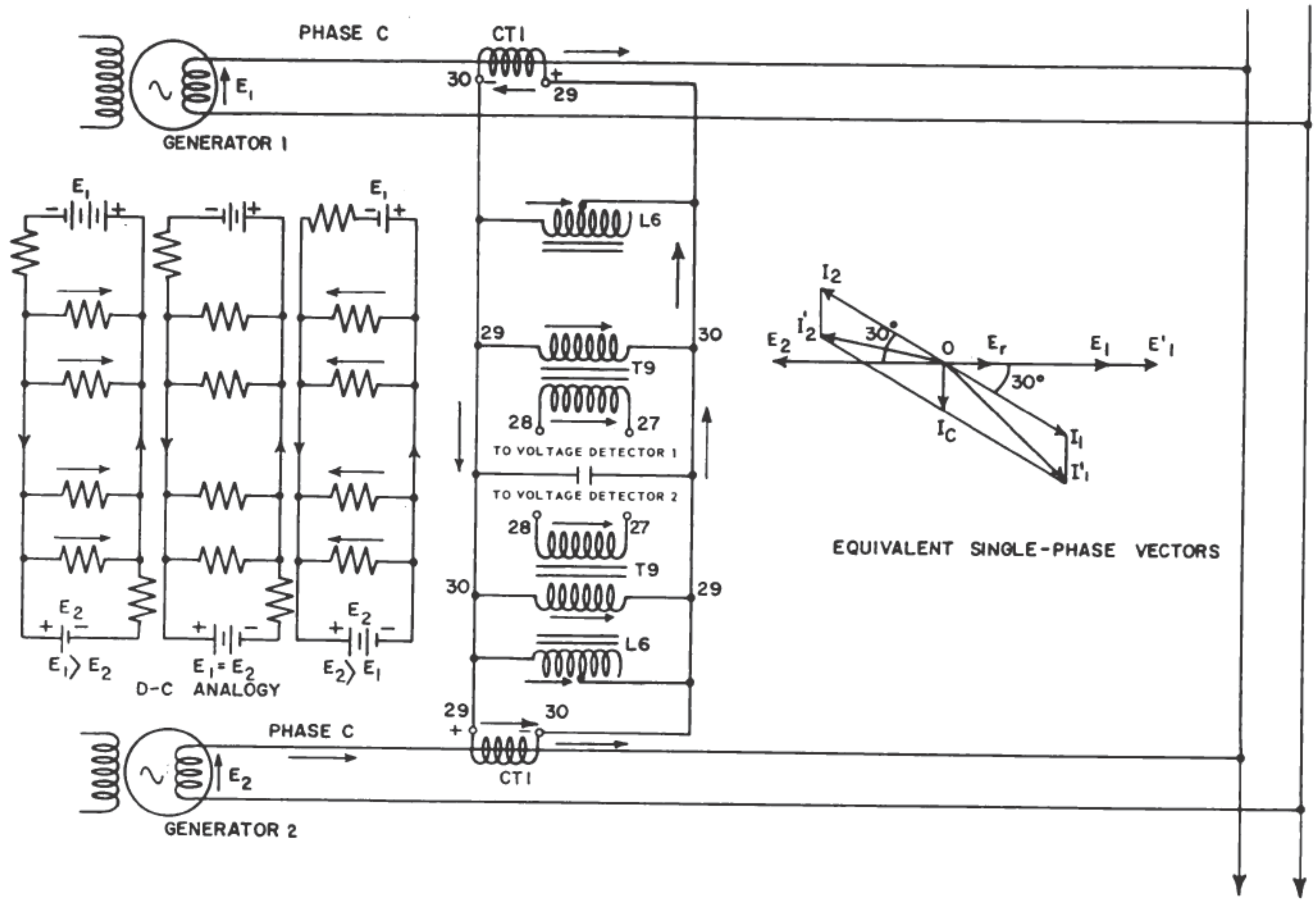


Figure 6—28.—Cross-current-compensation schematic.

citation on either generator would cause a circulating current to flow between the generator armatures with accompanying change of power factors. The circulating current would be accompanied by a lagging power factor on the over excited generator and a leading power factor on the under excited generator. Although the inherent regulation of these machines tends to correct the situation, the cross-current-compensation network provides a more sensitive device that aids materially in correcting the condition so that the circulating current is reduced to zero and the power factors of the generators are equalized.

When the proper condition exists, there is no circulating current between the generators, and the output voltage between terminals 27 and 28 of transformer *T*9 is zero. If, for example, the excitation of generator ① is increased so that E_1 is greater than E_2 (fig. 6–28), the circulating current combines with the load component of current as shown in the vector diagram increasing the total current supplied by generator ① from I_1 to I_1' and decreasing the total current of generator ② from I_2 to I_2'. Thus, the core flux of *CT*1 in phase C of generator ① increases, and that of *CT*1 in phase C of generator ② decreases. This action causes the secondary voltage of *CT*1 of generator ① to increase and that of *CT*1 of generator ② to decrease. The secondary of *T*9 of generator ① is connected to terminals 27 and 28 of phase C of the *T*7 primary of the voltage detector of generator ① so that the signal developed by *T*9 adds to the phase C voltage of *T*7. Thus, the increased input to the voltage detector results in an increased output signal of the voltage detector of generator ①. The action is like that previously described for over-voltage with single-generator operation. The voltage regulator lowers the field excitation of generator ①.

The secondary of T9 of generator ② is connected to terminals 27 and 28 of phase C of the *T*7 primary of the voltage detector of generator ② so that the signal developed by *T*9 subtracts from the phase C voltage of *T*7. Thus,

the decreased input to the voltage detector results in a decreased output of the voltage detector of generator 2 with increased field excitation being supplied by the voltage regulator. The simultaneous action of both voltage detectors quickly reduces the circulating current to zero.

If the conditions reverse and E_2 exceeds E_1, the direction of the resultant voltage and circulating current will reverse with respect to its direction in the vector diagram and in the circuit of figure 6–28. In this case the secondary voltage of *T*9 of generator 2 will experience a phase shift of 180°, and the output signal of *T*9 to the voltage detector of generator 2 will become additive with the voltage of phase C of *T*7. Thus, the voltage regulator of generator 2 will weaken the field of generator 2. At the same time, the direction of the output voltage of *T*9 of generator 1 will reverse its direction with respect to that indicated in figure 6–28. This action will cause the output of *T*9 to buck the voltage of phase C of *T*7 of generator 1, and the reduced output of the voltage detector will cause the field excitation of generator 1 to be increased. Again, the simultaneous actions of both voltage regulators equalize the voltages, and the circulating current is reduced to zero. When this condition is effected, the outputs of the secondaries of *T*9 are reduced to zero.

A d-c analogy of the cross-current-compensation network is illustrated at the left of figure 6–28. When $E_1 = E_2$ (center), no current flows through the shunt resistors. This condition corresponds to the proper condition of parallel operation of the two generators.

QUIZ

1. (a) In what general applications are magnetic amplifiers used aboard ship? (b) Name a more specific application.
2. What is the relation between the generated voltage and the d-c field current of an a-c generator?
3. What is the function of an ideal automatic excitation system for an a-c generator?

REFERRING TO FIGURE 6–2 FOR QUESTIONS 4 AND 5:

4. From what source is the field current of the a-c generator derived?

5. (a) What is the effect on X_m when increasing the d-c saturating current in the control winding of the saturable current transformer? (b) What is the effect of decreasing X_m on I_{fi}? (c) What is the effect of decreasing I_{fi} on E_t?

6. (a) Name the six major components comprising the voltage regulator portion of the system illustrated in figure 6–6. (b) Name the two major components of the associated static excitation system. (c) Describe the cascade connections of the magnetic amplifiers employed in this voltage regulator system. (d) What is the approximate overall gain of the control-current circuits in this voltage regulator?

7. In figure 6–7: (a) What are the principal components of the input circuit? (b) What is the nature of the $T3$ output? (c) What is the nature of the $T2$ output?

8. Referring to figure 6–8, what is the purpose of the reference circuit?

9. Referring to figure 6–9, in the voltage-regulator comparison circuit, what is the arithmetic relation between the reference current I_1, the signal current I_2, and the current that is effective in controlling the $1SX$ stage?

10. What is the function of Rheo. 4 in figure 6–9, B?

REFERRING TO FIGURE 6–10, A AND B FOR QUESTIONS 11 THROUGH 14:

11. What is the effect of an increase in the generator terminal voltage on the signal current, I_2, in the comparison circuit?

12. What is the effect of an increase in the signal current on the control current of $1SX$?

13. What is the effect of a swing of control current in a positive direction in $1SX$ on the average load current of $1SX$?

14. What is the effect of a weakened field on the (a) generated voltage and (b) the terminal voltage?

15. In figure 6–11, A, what is the function of the reactive compensation circuit?

16. In figure 6–12, what is the function of the stabilizing circuit?

17. In figure 6–13, what are the three functions that the manual control and auxiliary unit provide?

18. Referring to figure 6–14, in the manual control circuit, what is the function of *CR*6?

19. When the voltage regulator is operating in manual control, how many stages of amplification are used?

20. What is the purpose of the auxiliary 40-kw, d-c generator used with the static excitation and voltage regulation equipment for a ship's service generator?

21. What device is employed in the 400-cycle motor generator set between the motor and the generator to provide speed regulator coupling?

22. (a) To what are the two independent rotating members of the magnetic particle clutch connected? (b) With what is the working gap between the two independent rotating members of the clutch filled? (c) How is the magnetic field strength, as determined by the current in the control coil, related to the difference in speed between the motor and generator?

23. What is the function of the magnetic clutch speed regulator?

24. Name the five principal components of the accessory control equipment used with the 5-kw, 120-v, 3-phase, 400-cycle generator.

25. What are the three principal components of the motor controller used with the 400-cycle power supply?

26. What is the function of the EMERGENCY switch?

27. In figure 6–21, what are the four principal circuit components of the speed regulator?

28. When the master switch is operated to the start position, why does the generator not come up to speed simultaneously with that of the driving motor?

29. In figure 6–21, when the motor generator comes up to speed, what is the action of relay *S*?

30. Referring to figure 6–22: (a) In the resonant detector circuit, what is the purpose of the *L–C* networks? (b) How is this function accomplished?

31. Referring to figure 6–22: (a) In the power amplifier stage, what is the effect on the voltage available for the control coil of the magnetic particle clutch if the current in winding 2*C*–3*C* is greater than the current in winding 1*C*–3*C*? (b) If the current in winding 1*C*–3*C* is greater than the current in winding 2*C*–3*C*?

32. How will a decrease in the frequency of the input voltage of the speed regulator affect the magnetic particle clutch?

33. What is the function of the parallel operation relay?

34. In figure 6–23, what is the function of the load division assembly?

35. Referring to figure 6–23, why is the resistor $R9$ common to both resonant detector circuit and the load division assembly?

36. Referring to figure 6–22: (a) How many control voltages act on the control winding of reactor $4SX$? (b) Across which circuit components are these voltages derived? (c) How does an increase in unequal load division affect the voltage across $R9$? (d) How does a variation in frequency from normal affect the output voltage across $R1$–$R2$? (e) A change in either of these voltages of an equal magnitude has what relative effect on the preamplifier stage ($4SX$) output? (f) A change of either of these voltages acts to do what to the voltages supplied to the control coil of the magnetic particle clutch? (g) The signal fed to the speed regulators results in decreased clutch excitation to the system with what relative motor current (higher or lower)?

37. (a) What are the three principal components of the 5-kw, 400-cycle power supply voltage regulator? (b) What is the function of the voltage detector? (c) What is the function of the preamplifier? (d) What is the function of the power amplifier?

38. (a) What primary source is used to provide the initial excitation for the 5-kw, 400-cycle generator field when the automatic-manual control switch is in the start position? (b) From which source does the generator derive its field power when the automatic-manual transfer switch is in the manual position? (c) Referring to figure 6–26, from which primary source does the control winding $1C$–$2C$ of the power amplifier $1SX$ derive its power under conditions of manual control? (d) In figure 6–26, what is the function of Rheo 2? (e) What is the effect of an increase in the control current of $1SX$ on the generator field current?

REFERRING TO FIGURE 6–27 FOR QUESTIONS 39 THROUGH 47:

39. (a) From which harmonic of the 400-cycle generator output voltage is the d-c control current of the voltage detector derived? (b) What happens to the fundamental frequency components in the output of $T7$? (c) Why?

40. What is the function of potentiometers $P1$, $P2$, and $P3$?

41. To what circuit is the output of the voltage detector fed?

42. What is the relation between the magnitude of the control current and the output current of 3*SX*?

43. To what circuit is the output of the preamplifier, 3*SX*, fed?

44. What is the relation between the output of 1*SX* and the control current derived from 3*SX*?

45. (a) When the generator bus voltage is low, what is the effect of the bias flux on the core of 1*SX*? (b) What happens to the impedance of the load windings of 1*SX*? (c) What happens to the generator field current?

46. If the generator output voltage increases, what is the effect on: (a) The control current input from 3*SX* to 1*C*–2*C* of 1*SX*? (b) The core flux of 1*SX*? (c) The impedance of the load windings of 1*SX*? (d) The generator field current? (e) The generator voltage?

47. What is the effect of increased load current in phase A of the generator on: (a) The voltage developed across inductor *L*2*A*? (b) The voltage supplied to the load winding of phase A of 1*SX*? (c) The field current? (d) The generated voltage?

REFERRING TO FIGURE 6–28 FOR QUESTIONS 48 THROUGH 50:

48. What is the function of the cross-current-compensation assembly?

49. When no circulating current exists between the two generators, what is the magnitude of the output voltage between terminals 27 and 28 of *T*9?

50. When the excitation of generator 1 is increased so that E_1 is greater than E_2, what is the effect on the: (a) Total current supplied by generator 1? (b) Total current supplied by generator 2? (c) Core flux of *CT*1 in phase C of generator 1? (d) Core flux of *CT*1 in phase C of generator 2? (e) Secondary voltage of *CT*1 of generator 1? (f) Secondary voltage of *CT*1 of generator 2? (g) Input voltage to phase C of the voltage detector of generator 1? (h) Field excitation of generator 1? (i) Input voltage to phase C of the voltage detector of generator 2? (j) Field excitation of generator 2? (k) Circulating current between the two generators?

CHAPTER 7

GYROCOMPASS EQUIPMENT

The gyrocompass is a standard equipment on all naval vessels. It is used for navigation, fire control, and search radar, and is maintained by the I. C. Electrician.

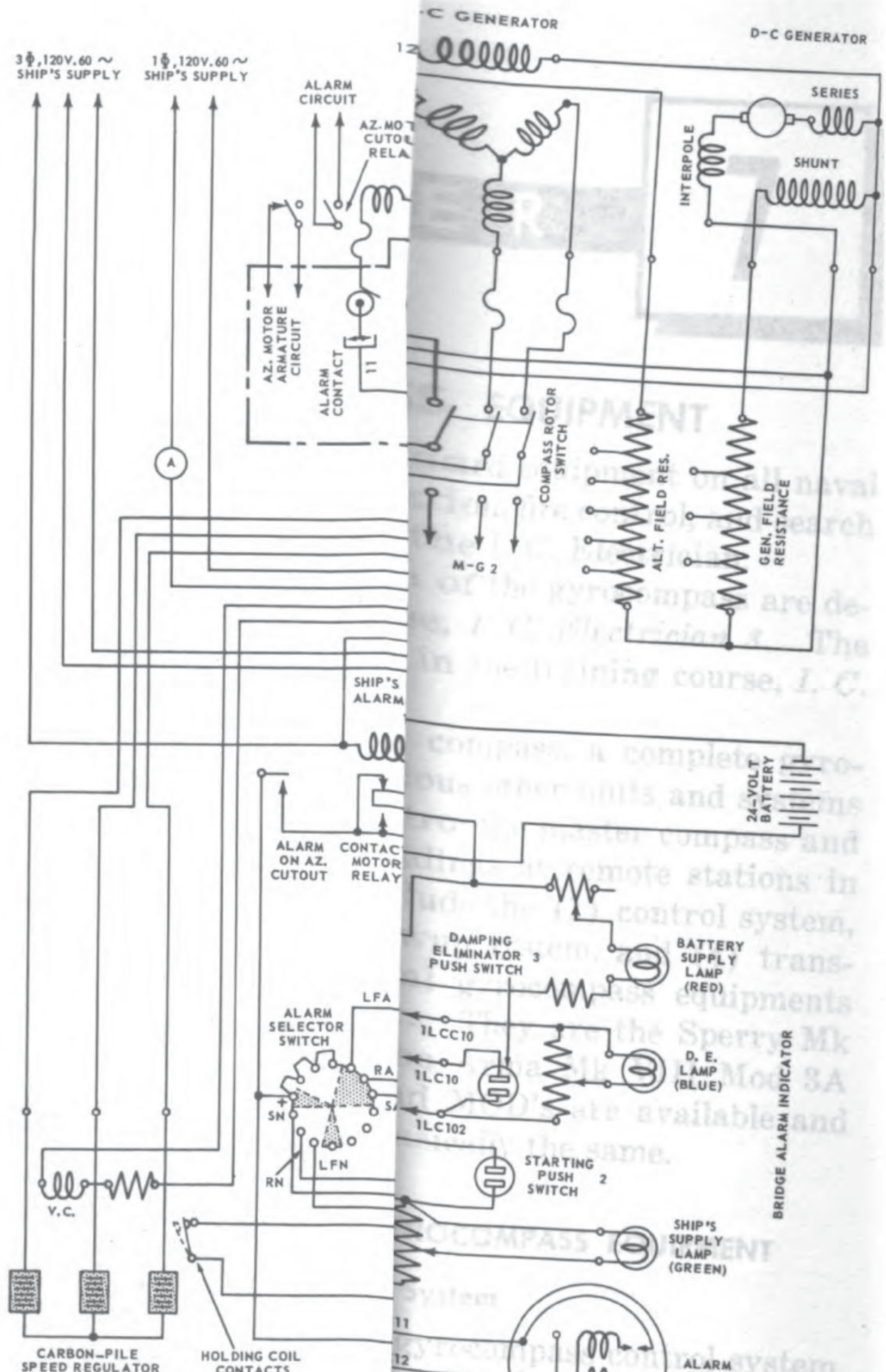
The principles of operation of the gyrocompass are described in the training course, *I. C. Electrician 3*. The master compass is described in the training course, *I. C. Electrician 2*.

In addition to the master compass, a complete gyrocompass system includes various other units and systems necessary to operate and control the master compass and to duplicate the compass readings at remote stations in the ship. These systems include the (1) control system, (2) alarm system, (3) followup system, and (4) transmission system. Two typical gyrocompass equipments are described in this chapter. They are the Sperry Mk XI Mod 6 equipment and the Arma Mk VIII Mod 3A equipment. Newer MK's and MOD's are available and under development and are basically the same.

SPERRY MK XI MOD 6 GYROCOMPASS EQUIPMENT

Control System

The Sperry Mk XI Mod 6 gyrocompass control system consists of a motor-generator, speed regulator, control panel, battery throwover panel, and bridge alarm indica-



3 Φ, 120V. 60 ~ SHIP'S SUPPLY
1 Φ, 120V. 60 ~ SHIP'S SUPPLY
ALARM CIRCUIT
D-C GENERATOR
SERIES
INTERPOLE
SHUNT
AZ. MOTOR ARMATURE CIRCUIT
ALARM CONTACT
COMPASS ROTOR SWITCH
ALT. FIELD RES.
GEN. FIELD RESISTANCE
M-G 2
SHIP'S ALARM
24-VOLT BATTERY
ALARM ON AZ. CUTOUT
DAMPING ELIMINATOR 3 PUSH SWITCH
BATTERY SUPPLY LAMP (RED)
ALARM SELECTOR SWITCH
LFA
1LCC10
1LC10
1LC102
RA
SA
SN
RN
LFN
D. E. LAMP (BLUE)
BRIDGE ALARM INDICATOR
STARTING PUSH SWITCH 2
V.C.
SHIP'S SUPPLY LAMP (GREEN)
ALARM BELL
CARBON-PILE SPEED REGULATOR
HOLDING COIL CONTACTS
11
12

tor, with the necessary apparatus for the operation and control of the master compass. The principal components of the control system are illustrated by the schematic diagram in figure 7–1.

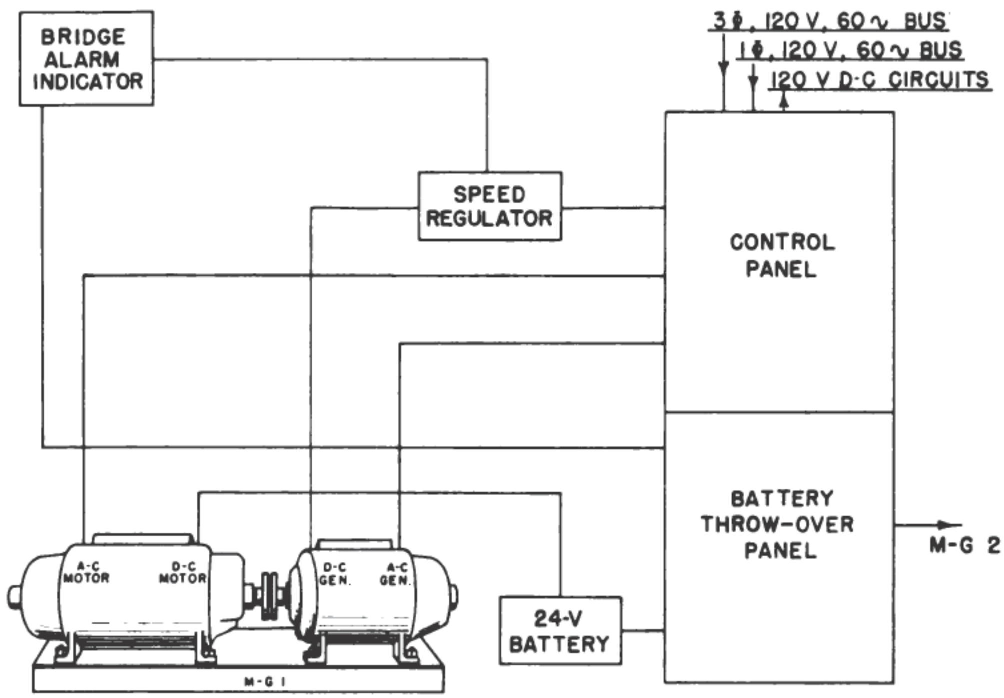


Figure 7—1.—Schematic diagram of Sperry Mk XI Mod 6 gyrocompass control system.

The gyrocompass drive system consists of the primary and emergency sources of power. The primary power source is the ship's 3-phase, 120-volt, 60-cycle supply, and the emergency power source is the 24-volt battery supply as illustrated in the schematic wiring diagram of figure 7–2.

MOTOR-GENERATOR. — Two separate motor-generator sets are provided with each complete Sperry gyrocompass equipment. Each set consists of an induction motor, a d-c emergency motor, an a-c generator, and a d-c generator (fig. 7–1). The induction motor and the d-c emergency motor are mounted on a common shaft in a single frame. The a-c generator and the d-c generator are also

mounted on a common shaft in a single frame. The shafts of these two units are directly coupled together. Each motor-generator set is assembled as a complete unit and mounted on a single bedplate.

The INDUCTION MOTOR is a 3-phase, 120-volt, 60-cycle, wound-rotor motor with slip rings. Under normal operating conditions, the induction motor drives the d-c motor, the a-c generator, and the d-c generator. It operates at a constant speed of 1460 rpm (necessary for the a-c generator to deliver a constant 3-phase output of 55 volts at 195 cycles), which is maintained constant by means of a speed regulator that compensates for a maximum of ±10% variations in the ship's primary power supply frequency.

The D-C MOTOR is a shunt-wound machine. Under normal conditions of induction motor drive, the d-c motor operates as a self-excited d-c generator for charging the battery with a continuous-duty rating of 27 volts at 7 amperes.

Under emergency operating conditions because of failure in the ship's 3-phase supply to the induction motor, the d-c motor operates from the battery supply to drive the a-c and d-c generators. As a d-c motor, it has an intermittent-duty rating of 22.5 volts at 70 amperes.

The A-C GENERATOR is a 3-phase, 60-volt, 195-cycle inductor-type generator having 16 polar projections. Both the field and the armature are stationary. The 16 polar projections (inductors) rotate continuously at approximately 1,460 rpm, thereby varying the magnetic field flux through the armature windings and generating a-c voltages at a frequency of 195 cps. The armature consists of a wye-connected, 3-phase winding, and the field consists of a single d-c winding. Slip rings are not required with this type of generator. This machine supplies power to drive the gyro rotor and to energize the amplifier and the followup system.

The D-C GENERATOR is a 120-volt, compound-wound, interpole, self-excited generator. This machine supplies

excitation for its own fields, the a-c generator field, and the azimuth-motor field. It also supplies d-c power for the damping eliminator, the azimuth-motor cutout relay, the dead reckoning equipment (DRE), and the voltage coil of the speed regulator.

SPEED REGULATOR.—The speed regulator (fig. 7–2) is a separate unit located adjacent to the motor-generator sets. It compensates for variations in the ship's supply voltage or frequency to maintain the speed of the induction motor constant and thereby causes the a-c generator to deliver a constant output to drive the gyro motor. The same speed regulator is used for each of the two motor-generator sets because they are not operated simultaneously.

The speed regulator consists of a wye-connected, carbon-pile voltage regulator connected in the form-wound rotor circuit of the 3-phase induction motor by means of slip rings.

The actuating coil of the speed regulator is connected in a shunt circuit across the output terminals of the d-c generator. It therefore responds to changes in d-c output voltage occasioned by any changes in speed of the motor generator. The voltage coil, VC, attracts a spring-loaded pressure arm that varies the pressure on the carbon piles in accordance with any change in voltage across the coil.

If the ship's supply voltage or frequency increase, the induction motor-rotor currents will increase. This action will cause a slight increase in the speed of the motor-generator. The consequent slight increase in d-c generator voltage causes the voltage coil of the speed regulator to attract the spring-loaded arm. This action decreases the pressure on the carbon piles. The accompanying increase in rotor-circuit resistance will restore the rotor currents to their normal value and check the rise in speed and d-c generator output voltage.

A dashpot damper is connected to the pressure arm to prevent hunting when rapid changes occur in the voltage or frequency.

A holding-coil contact on the speed regulator is in series with the holding coil of the battery throwover relay (on the battery throwover panel). This contact is operated by the pressure arm and at reduced speed opens the relay to cut in the battery supply.

If the regulated speed changes with heavy loads, and the fault is not in the connections or in the generator, the difficulty may be due to lack of pressure on the carbon piles. The initial adjustment of the pressure on the carbon piles is by means of the large knurled nut located on the left-hand side of the regulator (fig. 7–3). This knurled nut extends through the left-hand bracket and bears against a hinged plate that, in turn, bears against the carbon piles. This nut can be screwed IN or OUT on the stud, D, to increase or decrease the pressure of the hinged plate on the carbon piles simultaneously. This adjustment also regulates the range that the armature can swing between the inside and outside armature stops. The more the pressure on the piles the smaller will be the range of swing of the armature.

The pressure on the carbons is adjusted with the voltage coil deenergized and with the outside armature stop removed. The armature is pulled down against the spring tension of the two adjusting nuts (located above the knurled nut), which decreases the pressure on the carbon piles. The knurled adjusting nut is screwed IN until the armature lever arm barely makes contact with the internal armature stop when the armature is released. The internal armature stop consists of a stationary stop and a movable stop. The stationary stop is secured to the right-hand bracket that supports the armature and voltage coil assembly. The movable stop is attached to the armature lever arm adjacent to the counterweight. The knurled nut is now loosened one-half turn to allow the movable stop to go back freely against the stationary stop. The outside armature stop is now replaced. Never try to change the speed setting by adjusting the knurled nut, as

this adjustment will result only in reducing the range of the regulator.

The operating speed of the motor-generator can be regulated by means of the two adjusting nuts at point A, mounted on a stud that protrudes through the left-hand bracket (fig. 7–3). The stud is attached to one end of a tension spring. The other end of this spring is attached to a movable link that is secured to the armature lever arm above the pivot point. The movable link protrudes through a bracket on the right-hand side of the regulator.

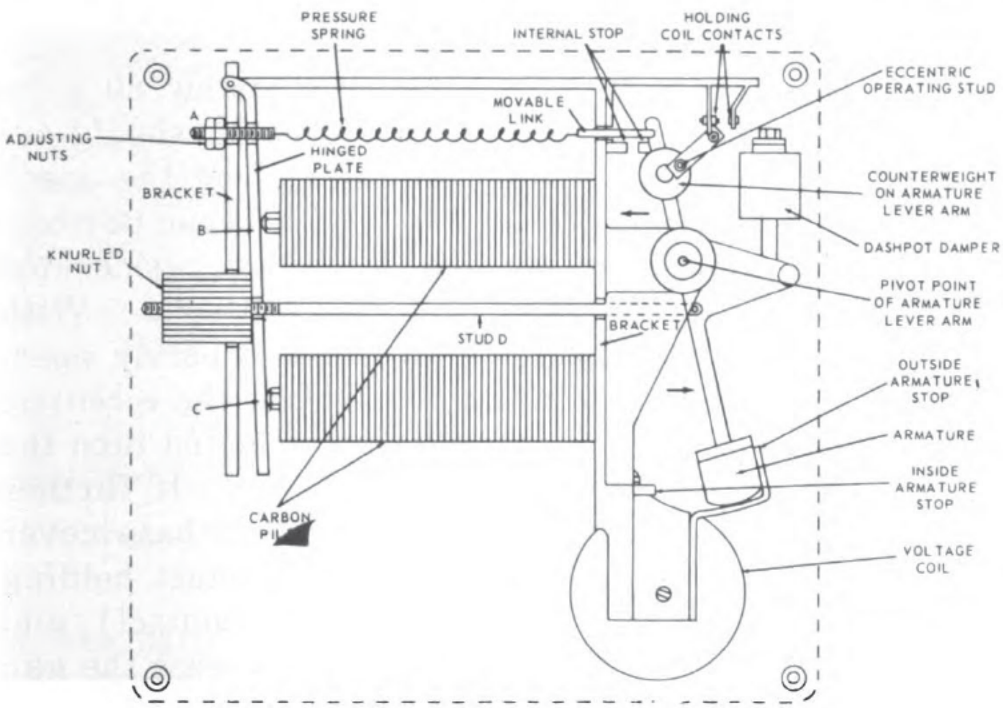


Figure 7—3.—Speed regulator schematic.

To increase speed, the adjusting nuts (one nut serves only as a lock nut) are screwed further IN on the stud. This action increases the spring tension at point A, which (1) increases the pull against the armature lever arm, and (2) increases the pressure applied to the carbon piles at points B and C through stud D. This action increases the spring pressure on the carbon piles and decreases the resistance in the rotor circuit of the induction motor, thereby increasing the regulated speed of the motor-generator.

Conversely, to reduce speed, the adjusting nuts are screwed farther OUT on the stud, which reduces the spring pressure on the carbon piles and increases the resistance, thereby reducing the regulated speed.

The dashpot is of the inverted air type provided with a graphite plunger and air-vent adjustment. This vent should be adjusted so as to barely overcome any tendency of the regulator to hunt when the load is light or when starting up. Care should be taken not to close the vent too much because this will reduce the sensitivity of the regulator. The dashpot action is continuous regardless of temperature changes.

When the a-c supply drops to approximately 80 volts and/or 54 cycles, the carbon pile pressure arm should automatically open the holding coil contacts on the speed regulator. The adjustment of these contacts can be made by supplying the induction motor of the motor-generator with 54-cycle, 3-phase power at about 103 volts. With this supply the holding coil contacts should barely open. If they do not open, loosen the nut holding the eccentric operating stud on the contact operating arm and turn the stud with a wrench until the contacts open. If further adjustment is required, remove the contact base cover (not shown in the figure). Loosen the contact holding screws (holding either the fixed or movable contact), and adjust the contacts to either increase or decrease the gap as desired.

COMPASS CONTROL PANEL.—The compass control panel is located at the upper left-hand section of the gyrocompass switchboard (fig. 7-4). The control panel is used to control and indicate the operating conditions of the master compass. The ship's 3-phase, 120-volt, 60-cycle power supply and the ship's single-phase, 120-volt, 60-cycle power supply are connected directly to terminals on the back of the compass control panel. The 3-phase, 120-volt, 60-cycle power supply is fed from these terminals on the control panel through the battery throwover relay

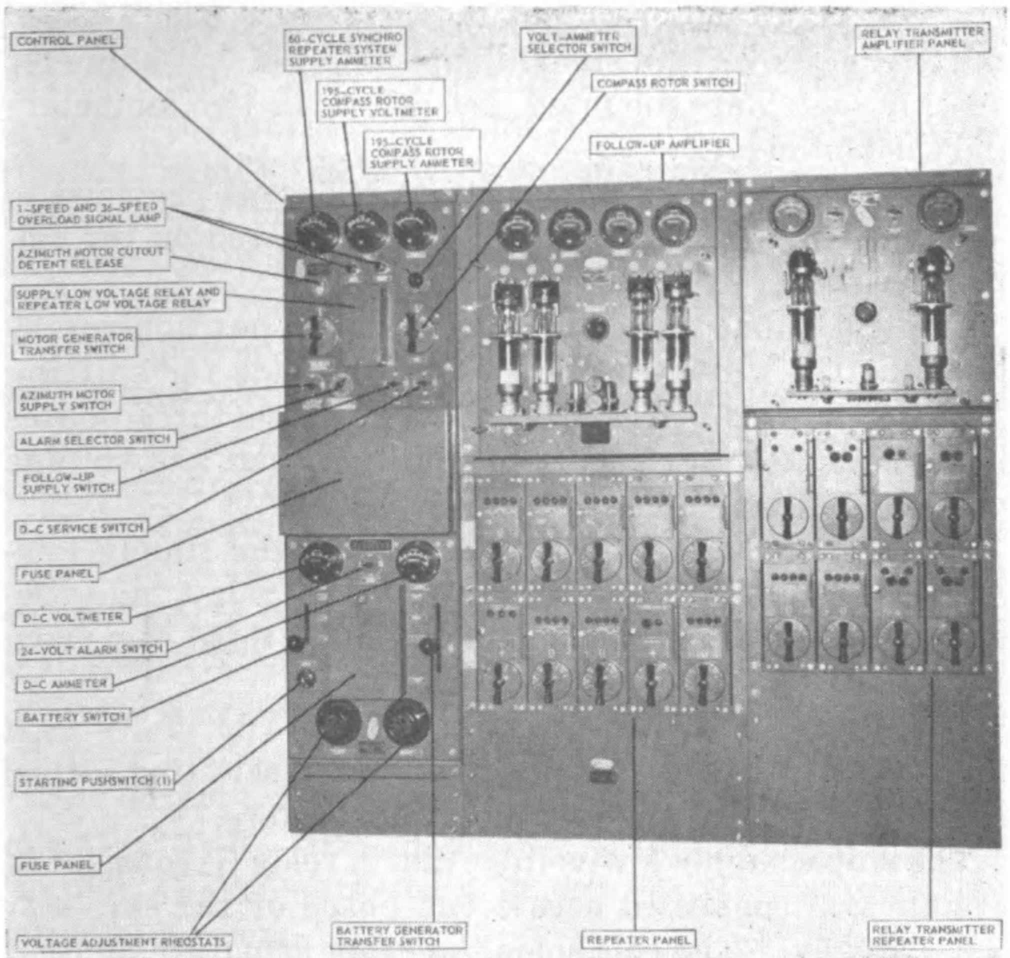


Figure 7—4.—Sperry Mk XI Mod 6 gyrocompass switchboard.

on the battery throwover panel to the motor-generator transfer switch on the compass control panel. The necessary switches and fuses for these power supplies are included on the I. C. switchboards and are not provided on the gyrocompass switchboard.

Two a-c ammeters and an a-c voltmeter are mounted at the top of the control panel to indicate the operating conditions of the master compass. One ammeter indicates the 60-cycle alternating current supplied to the synchro repeater system by the master compass transmitter, and the other ammeter and the voltmeter indicate the 195-cycle current and voltage respectively supplied by the 3-phase, a-c generator to the gyrocompass rotor.

The azimuth-motor cutout detent release, the 1-speed and 36-speed overload signal lamps, and the volt-ammeter selector switch are mounted just below the two ammeters and the voltmeter.

The azimuth motor cutout detent release is provided to reset the cutout after a fault has been cleared on the followup system.

The volt-ammeter selector switch is a 3-position rotary switch. The three switch positions provide for shifting the ammeter and voltmeter to any one of the three phases of the a-c gyro rotor supply to obtain current and voltage readings of the selected phase.

The motor-generator transfer switch, the supply low-voltage relay, the repeater low-voltage relay, and the compass rotor switch are mounted on the third row from the top.

The motor-generator transfer switch (fig. 7–2) is a double-throw rotary switch provided for selecting either one or the other of the two motor-generators.

The ship's supply low-voltage alarm relay 1 consists of a shunt coil connected across one phase of the ship's 3-phase supply. The coil holds the relay armature against the front contacts as long as this supply is available. If this supply fails, the armature drops and closes the back contacts to sound the alarm bell.

The repeater low-voltage relay 2 is similar to the supply low-voltage relay. If the ship's single-phase supply to the repeaters fails, this relay operates to sound the alarm bell.

The compass rotor switch connects the 3-phase, 55-volt, 195-cycle power from the a-c generator to the gyrocompass rotor.

The azimuth-motor switch, the alarm selector switch, the follow-up supply switch, and the d-c service switch are located at the bottom of the control panel.

The azimuth-motor switch controls the (1) rectified a-c supply circuit to the azimuth motor and (2) the d-c supply to the azimuth-motor field.

The alarm selector switch is a rotary switch with four positions marked (1) normal (2) low frequency, (3) repeater supply, and (4) ship's supply. In the NORMAL position, the alarm bell sounds if the ship's supply or the repeater supply fail or if the supply voltage or frequency fall below a pre-determined value. The alarm bell is silenced by turning the selector switch to the position indicating the trouble.

The followup supply switch is an on–off switch. In the ON position it energizes the followup panel from one phase of the 3-phase gyro supply, and heats the filaments of the amplifiers and rectifier tubes in the followup system.

If the followup switch is in the OFF position, the compass supply ammeter and voltmeter indicate the current and voltage to the gyro rotor only; whereas, if this switch is in the ON position, the meters will indicate the 195-cycle current and voltage to both the gyro rotor and the followup panel.

The d-c service switch is the master switch for the 120-volt, d-c circuit. It supplies the (1) damping eliminator circuits, (2) azimuth-motor field, and (3) azimuth-motor cutout relay coil.

The fuses for the compass control panel are within an enclosure located at the bottom of this panel.

BATTERY THROWOVER PANEL.—The battery throwover panel is located directly below the compass control panel (fig. 7-4). It is used to transfer automatically the gyrocompass circuits from the ship's 3-phase supply to the battery supply in the event of failure of the ship's supply. The 24-volt storage battery is normally connected to the battery-charging generator of the motor-generator set and floats on the line.

If the ship's 3-phase supply voltage or frequency drops below the predetermined value ($\pm 10\%$ of the normal value), the movement of the pressure arm on the carbon piles of the speed regulator will open the battery throwover relay holding coil contacts, thereby deenergizing this

relay. When this relay is deenergized, the (1) ship's 3-phase supply is disconnected from the motor-generator set, (2) battery is connected to the d-c motor (charging generator) as a primary power source so that the d-c motor becomes the prime mover for the motor-generator set, and (3) alarm bell rings.

When the ship's 3-phase power supply is restored, retransfer of the drive to the induction motor must be accomplished manually.

The battery throwover panel components discussed in the following paragraphs are identified in the gyrocompass drive system schematic wiring diagram (fig. 7-2).

A 24-volt alarm supply switch and a battery voltmeter and ammeter are mounted at the top of the battery throwover panel.

The 24-volt alarm supply switch is a separate switch provided for cutting out the supply to the entire alarm system.

The d-c ammeter and the d-c voltmeter connected between the battery switch and the battery-generator transfer switch, indicate the current and voltage respectively in the battery line.

The battery throwover relay is located on the back of the panel. This relay has six upper (main) contacts and one lower (interlocking) contact.

The battery throwover relay in figure 7-2 is shown in an energized condition. The upper contacts, 1 through 6, are read from left to right. All contacts (upper and lower), except the third are closed. When the holding coil deenergizes, the third contact is spring-closed and held. As shown, when energized the first and second contacts connect two phases of the ship's 3-phase supply to the motor-generator transfer switch on the compass control panel. The third and fourth contacts are alarm contacts; the third is open and the fourth is closed. The function of the alarm contacts is described in detail under ALARM SYSTEM OPERATION. The fifth and sixth contacts

shunt the series resistances in the field circuits of the two battery generators. The bottom contact is the interlocking contact and closes the circuit to the relay holding coil through the holding coil contacts on the speed regulator.

The fuses for the battery throwover panel are within an enclosure located in the center of the panel.

The battery switch and the battery-generator switch are located on the left-hand and the right-hand sides of the fuse enclosure, respectively.

The battery switch is a DPST lever-angle switch that connects the 24-volt battery supply to the battery throwover panel.

The battery-generator transfer switch is a DPDT lever-angle switch that connects the battery to one or the other of the two battery generators.

The starting pushswitch 1 is mounted below the battery switch. It is used to start the motor-generator and also to restore the circuit to the holding coil of the battery throwover relay after the system has been interrupted because of a failure of the ship's supply or low voltage and/or frequency. When the relay closes, the circuit through the interlocking contact is restored and, if the ship's supply voltage and frequency are high enough to permit the holding coil contacts on the speed regulator panel to be closed, the relay will remain closed; otherwise the relay will drop open again when the pushswitch is released. Additional pushswitches in parallel with the starting pushswitch on the battery throwover panel are located on the bridge alarm units so that, if desired, the compass equipment can be shifted back to the ship's supply from these stations.

Two voltage adjustment rheostats, one for each of the battery generators, are mounted at the bottom of the panel. These rheostats are used to adjust the generator-field resistance to control the charging rate of the battery when the machine operates as a generator. The rheostats are cut out when the machine operates as a motor, and

the resistance that is cut into the field by the battery throwover relay automatically increases the speed to the proper value.

BRIDGE ALARM INDICATOR.—The bridge alarm indicator is located in the pilot house. The alarm circuits are included in figure 7-2. The indicator includes a red, a blue, and a green indicator lamp, a damping-eliminator pushswitch, and a starting pushswitch. These components are enclosed within a metal case provided for bulkhead mounting. An external alarm bell is located adjacent to this indicator.

The red indicator lamp in the battery supply indicates operation of the compass equipment from the 24-volt battery supply.

The blue indicator lamp is in the damping-eliminator circuit as a warning whenever the damping-eliminator coil is energized.

The green indicator lamp in the ship's a-c supply is lighted as long as the ship's supply is connected to the compass equipment.

Each indicator lamp is provided with a series variable resistor to control the intensity of illumination.

The starting pushswitch ② in parallel with pushswitch ① is provided to close the battery throwover relay and thus to connect the ship's supply to the compass equipment.

The damping-eliminator pushswitch ③ in parallel with the automatic damping-eliminator switch on the master compass is manually operated to energize the damping-eliminator coil and thus remove damping when the ship makes a turn of more than 15° at a rate in excess of 40° per minute.

Alarm System Operation

The alarm system is provided to indicate (1) throwover to emergency battery because of a reduction of more than 10 percent of the ship's supply frequency or voltage, or both, (2) failure of the ship's supply to the synchro re-

peaters, (3) failure of the ships 3-phase a-c supply, and (4) failure of the compass followup system.

The alarm system includes the ship's supply low-voltage alarm relay ① (fig. 7–2) and the repeater low-voltage relay ②, previously described in connection with the compass control panel. It also includes the third and fourth contacts on the battery throwover relay, the alarm contact on the azimuth-motor cutout relay, the alarm supply switch on the battery throwover panel, the alarm selector switch on the compass control panel, the bridge alarm indicators, and alarm bell. The primary power for this entire alarm circuit is the 24-volt battery.

The alarm selector switch is used to locate the circuit in which trouble has occurred.

The bridge alarm indicators show when the compass is being driven by the emergency battery supply instead of the ship's supply, and also when the trouble has been cleared.

DROP IN FREQUENCY OR VOLTAGE.—A drop in the frequency or voltage of the ship's supply of more than 10 percent of normal will cause the speed-regulator contacts to open (fig. 7-2). This action deenergizes the holding coil and opens the interlocking contact on the battery throwover relay and transfers the gyrocompass system to the 24-volt battery supply. At the same time, the alarm contacts on the battery throwover relay close and sound the alarm bell. The ringing circuit is from the negative side of the battery to terminal 10 on the battery throwover panel and control panel, through the battery throwover relay contact to the *LFA* terminal on the alarm selector switch, to the positive (+) terminal of this switch, to terminal 11 on the control panel and battery throwover panel, through the alarm bell on the bridge indicator and back to the positive side of the battery, thereby completing the circuit and ringing the bell.

A second circuit is made when the battery throwover relay is opened. This circuit is from the *LFA* terminal on the battery throwover relay through the battery supply

lamp (red) on the bridge alarm indicators, and back to the positive terminal of the battery to complete the circuit and light the red lamp.

Therefore, two signals are made when the battery throwover relay opens on low voltage or frequency, causing (1) the alarm bell to ring, and (2) the battery supply lamp to glow (red) on the bridge indicator, showing that the equipment has been transferred to the battery supply.

To silence the bell, the alarm selector switch is turned counterclockwise (clockwise in fig. 7–2) from the NORMAL position to the LOW FREQUENCY position. This breaks the ringing circuit at the *LFA* terminal on the alarm selector switch and makes a new circuit available at *LFN* on the selector switch (the circuit is open at the *LFN* contact on the battery throwover relay). When the bell stops ringing as the selector switch is turned, the indication is that the relay has opened because of low frequency or voltage.

When the selector switch is turned to the LOW FREQUENCY position, the bell will stop ringing, but the red lamp will remain lighted until the frequency returns to normal and the ship's supply is restored.

When the ship's supply has returned to normal, the battery throwover relay will not reclose automatically because the lower interlocking contacts in the holding-coil circuit are open. The relay holding coil is energized only by manually operating starting pushswitch (1) on the battery throwover panel or pushswitch (2) on the bridge alarm unit. During battery operation, the battery throwover relay holding-coil contacts are held in the closed position by the operating coil of the speed regulator. Thus when the pushswitch is operated, the lower interlocking contacts of the throwover relay will close as the coil energizes, and the relay will be locked in by its own contact.

When the ship's supply is restored, relay alarm contacts will be made from terminal 10 through the battery throwover relay contact *LFN* to *LFN* on the alarm selector switch, through the switch to the positive terminal on this switch, through the alarm bell and back to the positive

terminal of the battery to complete the circuit and ring the bell. To silence the bell, the selector switch is turned to NORMAL position, showing that the ship's supply has been restored.

FAILURE OF REPEATER SUPPLY.—If the alarm selector switch is in the NORMAL position and the repeater supply fails, the repeater-supply alarm relay ② (fig. 7–2) will open the front contacts and close the back contacts to sound the alarm bell. This circuit is from the negative terminal of the battery, through the alarm fuse and battery alarm switch, to terminal 10, to contacts on repeater supply alarm relay on the compass control panel, through back alarm contacts to *RA*, to *RA* on alarm selector switch, through the switch to the positive terminal, to terminal 11 on the battery throwover panel, through alarm bell fuse to 4*LC*11 on bridge alarm indicator, through the bell to terminal 4*LC*12 back through the alarm battery switch and fuse, to the positive terminal of the battery. While the selector switch is at NORMAL position, the bell will ring, and also the (red) battery lamp on the bridge indicator will be lighted, giving a visual indication of trouble through the following circuit. This circuit is from *RA* on the repeater alarm relay to *RA* on the selector switch, to *LFA* on the selector switch, through the battery supply lamp fuse, through the battery lamp (red), to 4*LC*12, and to the positive side of the battery switch.

The alarm bell is silenced by turning the alarm selector switch from the NORMAL position to the REPEATER-SUPPLY position. This action opens the RA ringing circuit and the *LFA* circuit to the (red) battery lamp.

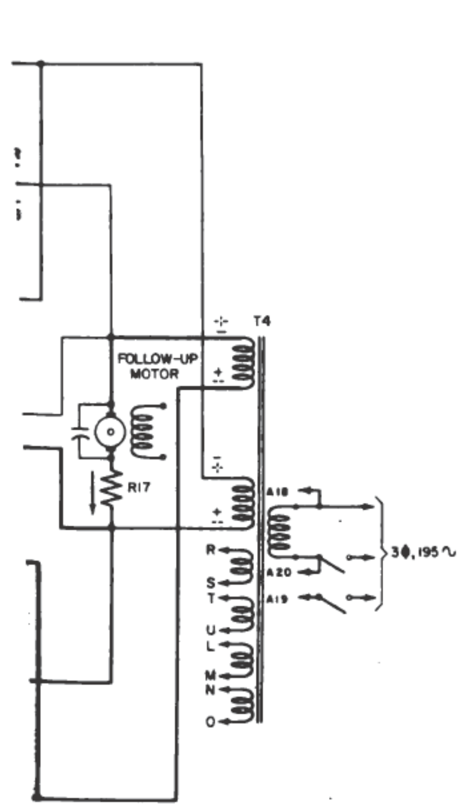
When the repeater supply is restored, the repeater supply alarm relay ② closes the front contacts and opens the back contacts to sound the alarm bell. This ringing circuit is from the negative terminal of the battery, through the alarm fuse and the alarm supply switch to terminal 10, through the front contacts of the repeater alarm relay ②, to *RN* to *RN* on the alarm selector switch, through the switch to the positive terminal on the switch,

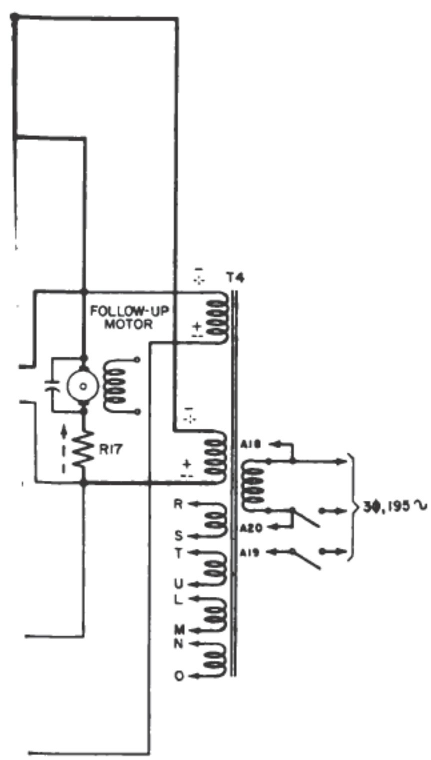
to terminal 11, through the alarm bell to 4*LC*12, through the alarm fuse and the alarm supply switch, and to the positive terminal of the battery. The bell rings, indicating that the repeater supply has been restored. To silence the bell, the alarm selector switch is turned to NORMAL.

FAILURE OF SHIP'S SUPPLY.—If the ship's supply fails, the ship's supply alarm relay ① opens and thereby opens the front contacts and closes the back contacts, completing a circuit through the contacts *SA* to the alarm bell. In addition, because failure of the ship's supply will affect the speed regulator, the holding coil contacts of this battery throwover relay will be opened, thereby opening the battery throwover relay and completing a second circuit through *LFA* on the relay to the (red) battery supply lamp and the alarm bell on the bridge alarm indicator. Failure of this supply will therefore ring the bell and light the battery supply lamp (red) as previously described. The green lamp will go out. To silence the alarm bell, the alarm selector switch is turned from NORMAL to SHIP'S SUPPLY. The bell will be silenced, but the battery supply lamp on the bridge indicator will remain lighted.

When the ship's supply is restored, the ship's supply alarm relay ① will be closed, thereby opening the alarm contacts and making contact on the front *SN* contacts. This action will ring the alarm bell again through the *SN* and positive terminals of the alarm selector switch. The bell is not silenced by turning the alarm selector switch from the SHIP'S SUPPLY position to the NORMAL position because the battery throwover relay is still open, and the bell will ring through the *LFA* circuit. Operating the starting pushswitch (on the bridge alarm indicator, or on the battery throwover panel) closes the battery throwover relay to interrupt the *LFA* circuits, silence the bell, and extinguish the red lamp.

FAILURE OF FOLLOW-UP SYSTEM.—If the follow-up sys-


T4
FOLLOW-UP
MOTOR
R17
A18
A20
A19
3φ, 195 ∿
R
S
T
U
L
M
N
O


T4
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tem fails, the alarm contact on the master compass will close and energize the azimuth-motor cutout relay coil that closes the alarm contacts and sounds the alarm bell. This circuit is from the negative side of the battery, through the alarm fuse and alarm battery switch, to terminal 10, to the cutout relay on the azimuth motor, through the relay to terminal 11, through alarm bell fuse and alarm bell, to 4*LC*12, through the alarm fuse and alarm battery switch, to 7*LC*10 and to the positive side of the battery. Trouble in this circuit should be corrected without delay because the selector switch does not control the circuit and cannot silence the bell. The red lamp will be lighted with the alarm switch at NORMAL. However, after the trouble has been corrected, the alarm selector switch must be returned to the NORMAL position if it has been turned to any other position. The (green) ship's supply lamp is always lighted when the ship's supply is connected to the gyrocompass equipment.

Follow-up System

The Sperry Mk XI Mod 6 gyrocompass followup system (fig. 7–5) comprises the azimuth followup mechanism (previously described with the master compass in the training course, *I. C. Electrician 2*) and the followup panel. The primary function of the followup system is to drive the phantom element of the master compass in azimuth. When the ship turns in one direction, the phantom element turns with it and away from the sensitive element. Thus, the phantom element must be driven at the same rate in the reverse direction to align it with the sensitive element.

FOLLOWUP PANEL.—The followup panel (fig. 7–4) is located adjacent to the compass control panel. It includes a voltage amplifier and a power amplifier. The voltage amplifier receives the signal from the followup transformer on the master compass, and the output of the voltage amplifier is fed to the power amplifier. The power amplifier provides the controlled power necessary to op-

erate the azimuth motor in response to the signals from the voltage amplifier.

The VOLTAGE AMPLIFIER consists of two twin triodes V1 and V2 (fig. 7–5). The signal voltage from the followup transformer is fed through slip rings to the input transformer, T2, the two primaries of which are in parallel. The magnitude of this signal is controlled by the potentiometer, P1.

The POWER AMPLIFIER consists of two pairs of thyratrons, GR1-GR2 and GR3-GR4 (fig. 7–5). The two thyratrons in a pair are paralleled in order in ensure continuous operation of the followup circuit in the event of tube failure. The thyratrons are grid-controlled rectifiers that produce a half-wave output.

When the ship turns, moving the phantom element away from the sensitive element, a signal voltage is induced in the followup transformer. This signal is amplified in the voltage amplifier and fed to the power amplifier, the output of which supplies the azimuth motor armature with half-wave pulses of voltage and current. The azimuth motor drives the phantom element back until it is alined with the sensitive element at which point the signal voltage becomes zero. In actual operation, the phantom element never becomes more than slightly displaced from the sensitive element because of the sensitivity of the followup control.

FOLLOWUP TRANSFORMER.—The followup transformer (fig. 7–5) comprises 3 coils mounted on an E-shaped laminated core. The primary coil 1 mounted on the center leg is connected to the 3-phase, 195-cycle compass rotor supply through a resistor that limits the current to a few milliamperes. It will be noted that one primary lead connects directly to one of the three phases; whereas the other lead ties to the common connection of two resistors bridged across the remaining two phases. This arrangement provides the proper phase relation between the input signal voltage and the bias and plate voltages of the gyrocompass followup circuits.

An armature carried on the sensitive element serves as a closing link in the double magnetic circuit of the followup transformer. The armature is positioned so that a small air gap is maintained between the armature and the transformer.

Secondary coils ② and ③ on the outside legs of the transformer are connected in such a manner that the induced voltage in one leg is 180° out of phase with the induced voltage in the other leg. Small capacitors, connected across the secondary coils, are in parallel resonance with the coils at 195 cycles in order to obtain the maximum voltage across the coils at that frequency. To balance the voltage output of the secondary coils when the armature is centrally located, two fixed resistors are connected across the capacitors.

OPERATION OF FOLLOWUP AMPLIFIER.—When the sensitive element and the phantom element are in proper alignment, the voltages induced in coils ② and ③ are equal, and the output voltage is zero. For this condition, the output signal from the voltage amplifier is zero, and the bias on the grids of the power amplifier tubes is such that a small plate current flows alternately in the *GR*1-*GR*2 group and the *GR*3-*GR*4 group. This current flows alternately in opposite directions through the followup motor armature, and therefore produces no motor torque. The purpose of this current is to keep the thyratrons warmed up and in readiness at all times to properly respond to a developed signal. A small displacement of the sensitive element from the phantom element in ONE direction unbalances the air gap in the magnetic circuit, thereby unbalancing the voltages induced in coils ② and ③. The output voltage is the difference between these two voltages and the phase of the output voltage corresponds to that of the larger of the two voltages. Thus, if the sensitive element is displaced from the phantom element in the OPPOSITE direction, the unbalance of the coil voltages is inverted and the output signal is shifted 180°.

Unlike conventional electron-tube amplifiers, the plates of $V1$ and $V2$ are supplied with an a-c voltage instead of the usual d-c supply. The amplifier circuits (fig. 7–5) are arranged in two channels, (one in heavy lines, the other in light lines) one for each direction of rotation of the azimuth motor. The input circuits of each channel of the voltage amplifier are connected in pushpull, and the outputs are also connected in pushpull. The input signal is amplified in the voltage amplifier and applied to the thyratron grids to provide the proper gating action of the thyratrons. The plate circuits of the thyratrons are connected in series with the azimuth-motor armature and the secondary of the a-c power supply. This arrangement provides power to the azimuth-motor armature through either of two pairs of grid-controlled, parallel-connected, half-wave rectifiers—one pair for each direction of rotation. Only one channel at a time is active. For example, the plate voltages of $V1A$, $V1B$, and $GR1$-$GR2$ are all of the same instantaneous polarity, and these tubes provide one of the two channels. Also the plate voltages of $V2A$, $V2B$, and $GR3$-$GR4$ have the same instantaneous polarity so that these tubes provide the second channel. The polarity of the plate voltages of the first channel is opposite to that of the second channel. In others words, they are 180° out of phase at all times.

For example, assume that the armature of the followup transformer is positioned so that the voltage induced in coil ② is larger than the voltage induced in coil ③. The input signal applied to $T2$ from the followup transformer is then assumed to be of a polarity that will cause the grid of $V1A$ to go more negative (fig. 7–5, A), and the grid of $V1B$ to go more positive during the half cycle that the plates of $V1$ are positive. The secondaries of $T2$ are wound so that the grids of $V1A$ and $V2B$ have the same polarity at any instant. This signal will cause the plate current of $V1A$ to decrease, and the plate current of $V1B$ to increase. Thus a positive going signal will be applied to the grids of $GR1$-$GR2$, causing them to conduct.

The polarities for the first half cycle are indicated by the solid polarity markings. Current will flow through the armature of the azimuth motor during this half cycle in the direction indicated by the solid arrow. The active channel is indicated in heavy lines. Twin triodes $V2A$ and $V2B$ do not conduct during this half cycle because their plates are negative.

During the second half cycle, the polarities reverse as indicated by the dotted polarity markings in figure 7–5, A. Twin triode $V1$ does not conduct during this half cycle because the plates of $V1A$ and $V1B$ are negative. Rectifiers $GR1$-$GR2$ do not conduct because their plates are negative. The signal at transformer $T2$ makes the grid of $V2A$ more negative and the grid of $V2B$ more positive. Plate current increases in $V2B$ and decreases in $V2A$. The negative-going output signal across $R2$ makes the grids of $GR3$-$GR4$ more negative, and these rectifiers are cutoff so that no current will flow through the armature of the azimuth motor during this half cycle. Hence, half-wave pulses of plate current from $GR1$-$GR2$ flow through the azimuth motor, which moves the phantom ring into alinement with the sensitive element. This action reduces the input voltage to transformer $T2$ to zero.

In the absence of a signal voltage, the a-c bias equalizes the currents in the $GR1$-$GR2$ and the $GR3$-$GR4$ power amplifier tubes. The output current of $GR1$-$GR2$ reduces to a small keep-alive value which flows through the follow-up motor armature during a portion of alternate half cycles. The output current of $GR3$-$GR4$ flows through the followup motor armature in the opposite direction during an equal portion of succeeding half cycles, and the azimuth motor stops.

If the phantom and sensitive elements are displaced in the opposite direction so that the voltage induced in coil 3 is larger than that induced in coil 2 (fig. 7–5, B), the input signal to $T2$ will reverse its phase with respect to the a-c voltage supplied to the plates of $V1$ and $V2$.

The polarities for the first half cycle are indicated by the solid polarity markings in figure 7–5, B.

During the first half cycle the plates of *V2A* and *V2B* are negative and do not conduct, and the plates of rectifiers *GR*3-*GR*4 are also negative and these tubes do not conduct. A positive-going signal is applied to the grid of *V1A* and a negative-going signal to the grid of *V1B*. The plate current in *V1A* increases and in *V1B* decreases. The resulting signal across *R*1 is applied to the grids of *GR*1-*GR*2 as a negative-going signal, and these rectifiers do not conduct.

During the second half cycle the plates of *V1A* and *V1B* are negative (dotted polarity markings), and these tubes do not conduct. The plates of rectifiers *GR*1-*GR*2 are also negative, and these tubes do not conduct. The signal on *T*2 makes the grid of *V2A* positive and the grid of *V2B* negative during the time both plates of *V*2 are positive. Thus, plate current increases in *V2A* and decreases in *V2B*. The positive-going signal across *R*2 makes the grids of *GR*3-*GR*4 positive during the half cycle that the plates are positive, and these rectifiers conduct heavily. The active channel is indicated in heavy lines. Current flows through the armature of the azimuth motor in the direction indicated by the dotted arrow. Thus, half-wave pulses of plate current flow through the azimuth-motor armature in the direction indicated in figure 7–5, B. This direction is opposite to that in figure 7–5, A. The motor moves the phantom ring into alinement with the sensitive element and the input voltage to *T*2 is reduced to zero. This action reduces the signal across *R*2 to zero, and the azimuth motor stops.

Each channel has its own rate circuit which provides an antihunt voltage for the power tubes that it controls. The rate capacitors are *C*6 and *C*7.

During the time that the plates of the voltage amplifier triodes are negative on alternate half cycles, the rate capacitors maintain the signal voltage across the choke

coils in the output circuits of the voltage amplifiers. For example, in figure 7–5, B, the signal developed in the active channel (heavy lines) charges rate capacitor $C7$ to the peak value of the signal voltage appearing across $L2$ and holds this voltage during the nonconducting half cycle as it slowly discharges through $L2$. As long as the signal holds up across $L2$, coupling capacitor $C3$ cannot discharge. As the signal diminishes because of the follow-up motor approaching synchronism, the magnitude of the signal voltage across $L2$ diminishes, thereby allowing $C3$ to discharge. This discharge sets up a negative-bias component across $R2$ that cuts off $GR3$-$GR4$ just before synchronism. This action permits the keep-alive current in $GR1$-$GR2$ to develop a motor torque in the opposite direction. Also before synchronism, the power amplifier tube that was firing for the greater length of the conducting half cycle will cutoff, allowing the other power amplifier tube to become more effective in reversing the motor torque so that over travel and hunting are prevented.

TUBE FAILURE.—There is an important feature about this followup circuit. It will continue to operate even if one of the voltage amplifier tubes and one of each pair of power amplifier tubes should fail. The remaining voltage amplifier and one of each pair of power tubes, a total of three tubes, will keep the system operating.

In normal operation each pair of power tubes passes a current of about 0.4 ampere when there is no signal on the grids. These currents are in opposite directions, and cancel each other as far as their effect on the azimuth motor is concerned. When the phantom moves to one side or the other, the current passed by one pair of tubes is increased, and that passed by the other pair is decreased. The difference between the currents passed by the two pairs of tubes is the resultant current that operates the azimuth motor.

If one channel of the voltage amplifier is not operating, its pair of power tubes will pass a current of 0.4 ampere

regardless of the position of the phantom. The other pair, being controlled by the active section of the voltage amplifier, passes more or less than 0.4 ampere, depending upon the position of the phantom. Thus, a difference in current still exists between the two pairs of power output tubes that is sufficient to operate the azimuth motor. Since only one of each pair of power tubes ordinarily operates, the failure of one tube in each pair has no effect on the functioning of the circuit.

Transmission System

The Sperry Mk XI Mod 6 gyrocompass transmission system provides a means of transmitting the readings of the master gyrocompass to a number of repeater compasses located at various stations in the ship. The 1-speed and 36-speed synchro transmitters (previously described with the master compass in *I. C. Electrician 2,* NavPers 10556) are driven by the azimuth followup motor that drives the phantom element in azimuth. These transmitters control the movement of the repeater compasses that indicate the readings of the master compass at the remote stations.

The transmission system includes the transmitter overload relays, repeater panel, relay transmitter repeater panel, relay transmitter, relay transmitter amplifier panel, differential alarm relay, and repeater compasses.

TRANSMITTER OVERLOAD RELAYS.—Two similar transmitter overload relays, mounted on the back of the compass control panel, provide a visual alarm when an overload occurs in the transmitter circuits. One relay is connected in the 1-speed transmitter circuit, and the other relay is connected in the 36-speed transmitter circuit (fig. 7–6). The relay consists of three legs with a coil on each leg. Each coil is connected in series with a transmitter stator lead. An increase in the current through any or all of the coils above a critical value attracts the relay armature, causing it to move. This action closes a contact that lights a red signal lamp on the panel front,

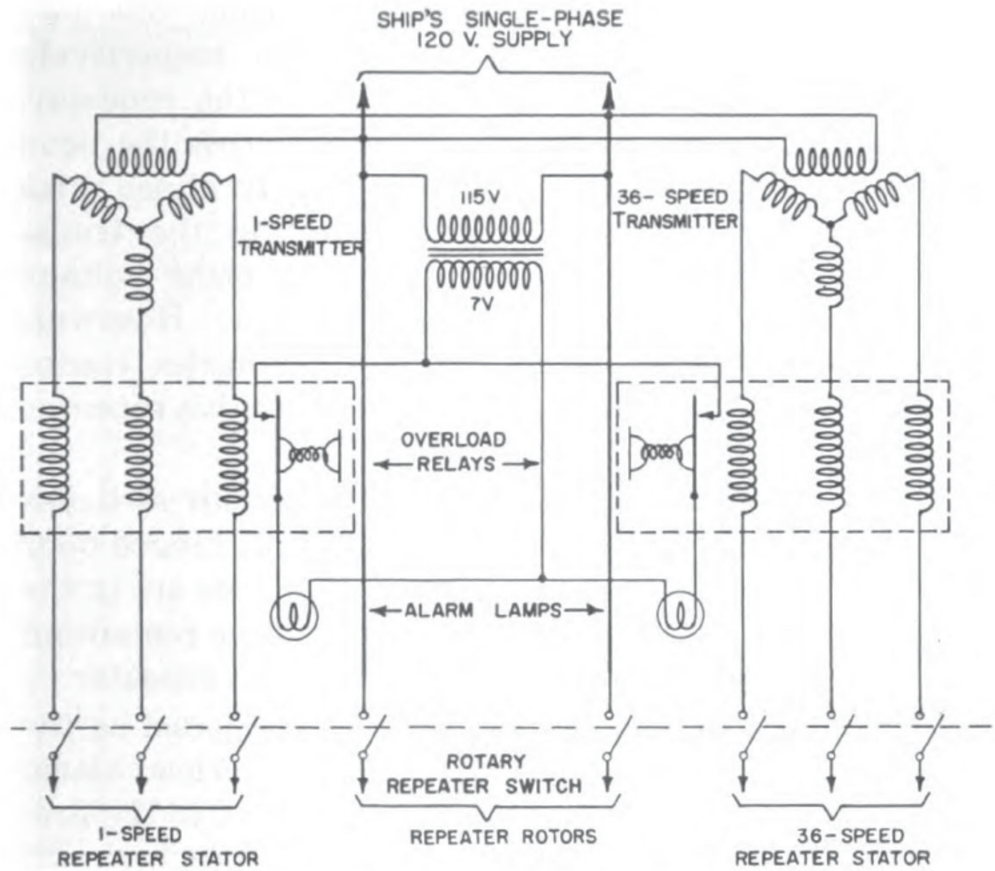


Figure 7—6.—Sperry Mk XI Mod 6 gyrocompass transmitter overload relay circuit.

indicating trouble in the transmitter circuit. A 115/7-volt transformer on the panel supplies the indicator lamp circuits.

REPEATER PANEL.—The repeater panel (fig. 7–4) is located below the followup panel. It comprises an assembly of rotary switches, and auxiliary equipment. Each switch with its associated fuses and overload indicating devices is assembled as a unit and can be withdrawn from the front of the panel for inspection and repair.

Each compass repeater switch is arranged to connect the circuits of two repeater compasses so that either one, or both, may be driven by the master compass transmitters.

Each repeater circuit, whether 1-speed or 36-speed, is provided with an overload indicator, comprising a trans-

former and a neon lamp. The transformer has two primaries, which are connected in series respectively with two of the three secondary leads to the repeater. The transformer secondary is connected across the neon lamp. When the repeater is approximately alined with the transmitter, the very small current in the transformer primaries does not generate sufficient voltage across the secondary to illuminate the lamp. However, excessive current in the transformer primaries causes the lamp to glow and thus indicate trouble in this repeater circuit.

Associated with each of the repeater circuit switches are four fuses, access to which is through the hinged door just above the switch handle. Two of the fuses are in the primary circuit to the 1-speed repeater, and the remaining two are in the primary circuit to the 36-speed repeater.

The rotary-type switch designated on the panel as the fire-control switch is not provided with an overload alarm because connections are made from this switch to the fire-control switchboard, which has an alarm for each circuit leaving the board. However, at the fire-control switch on the repeater panel the two indicators are (1) a pilot lamp, connected across the a-c supply to this switch and therefore illuminated as long as this supply is available, and (2) a transformer and neon lamp arranged to indicate when one or both of the a-c supply fuses blows.

The fuses are on the load side of the switch. The transformer has two primaries, one of which is connected across the 120-volt leads on the supply side of the fuses, while the other is connected across the same leads on the load side of the fuses. The two primaries are arranged so that normally their magnetomotive forces are in opposition, giving zero voltage across the secondary. However, failure of one or both fuses cuts out the primary on the load side of the fuses so that the remaining primary induces the secondary voltage, and thereby lights the neon lamps.

The rotary-type switch designated on the panel as the dead reckoning analyzer switch is provided to operate the DRA from the underwater log transmitter and the 1-speed transmitter on the master compass. This switch also supplies single-phase, 120-volt, a-c power and 120-volt, d-c power necessary for the operation of the DRA. Each of these circuits is provided with two fuses. A neon lamp across each fuse in the d-c circuit is lighted when a fuse blows in the circuit. A transformer and neon-lamp overload indicator (similar to the indicators in the repeater circuits) is connected in the 1-speed compass transmitter secondary to the own ship's course motor in the DRA.

RELAY TRANSMITTER REPEATER PANEL.—The relay transmitter repeater panel (fig. 7–4) is located adjacent to the repeater panel. This panel and the previously described repeater panel are arranged so that the repeater compasses can be connected to either the master-compass transmitter or to the relay transmitter, as shown in figure 7–7. The relay transmitter (described later) is an intermediate self-synchronous transmitter provided in the transmission system to actuate a number of compass repeaters without placing this load directly on the master compass transmitters.

The relay transmitter repeater panel includes eight rotary switches. These include a checking repeater switch, a fire-control switch, a relay transmitter supply switch, an emergency navigation transfer switch, two compass repeater switches, and two radar mast (special) switches.

The checking repeater switch connects the gyrocompass-room checking repeater either to the master compass or to the relay transmitter. Two fuses are connected in series with the primary leads on the load side of the switch. Two transformer and neon-lamp overload indicators (one for each circuit) are connected in the transmitter secondary circuits to indicate an overload in these

circuits. These indicators are similar to the overload indicators previously described in the repeater circuits.

The fire-control switch is connected only to the master-compass transmitter. The same blown-fuse indication is provided with this switch as that described for the fire-control switch on the repeater panel.

The relay transmitter supply switch connects the master-compass transmitters to the relay transmitter. A (green) pilot lamp indicates when the circuit to the relay transmitter is closed. A transformer and neon-lamp overload indicator provides a blown-fuse indication.

The emergency navigation transfer switch connects certain of the ships repeater compasses either to the master compass or to the relay transmitter. A red and green pilot lamp and four fuses are provided on the panel. The red pilot lamp indicates that the master signal cable to the compass control panel is energized. The green pilot lamp indicates that the repeater supply is available to the relay transmitter repeater panel. Two fuses are connected in each of the pilot lamp circuits.

Each compass repeater switch is arranged to connect two repeater compass circuits so that either one or both can be controlled by the master compass by way of the relay transmitter. The same blown-fuse indication is provided with each switch as is provided for each compass repeater switch on the repeater panel.

Each radar mast switch (special) is arranged to connect two mast radar cables to the transmission system so that either one or both can receive the ship's course indication from the master compass via the relay transmitter. A fuse is provided in each of the primary leads of a mast radar cable. A transformer and neon lamp are provided in the circuit that is similar to the one previously described to indicate a blown-fuse condition. A green pilot lamp, across the primary on the load side of the fuse, indicates when the circuit is energized.

RELAY TRANSMITTER.—In order to actuate a number of

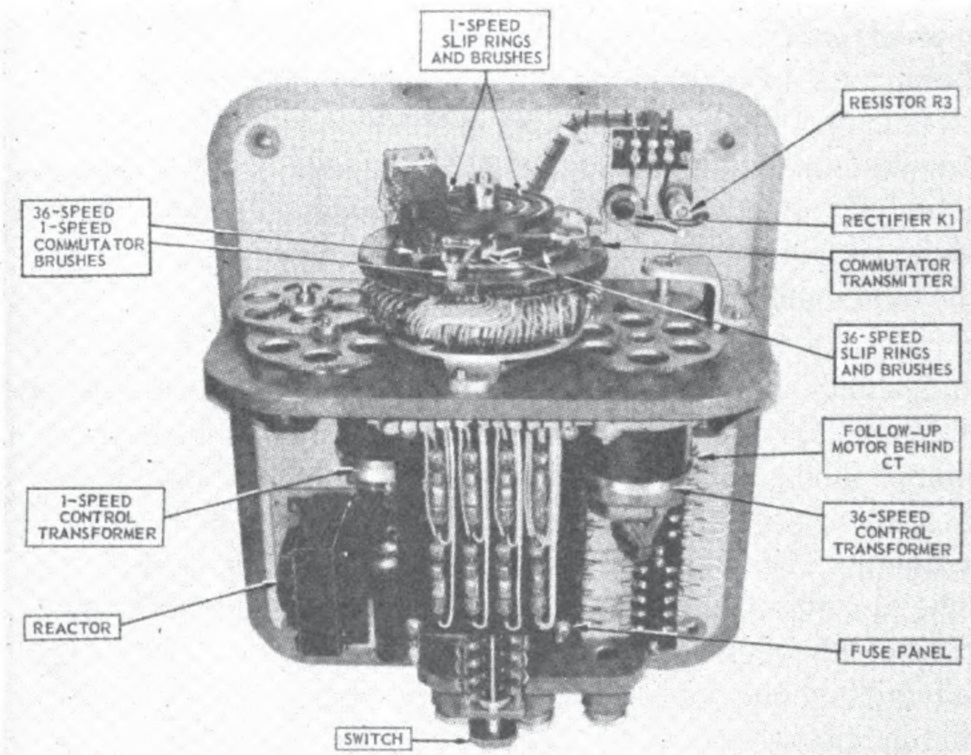
repeater compasses without imposing this load directly on the compass transmitters, an intermediate instrument known as a relay transmitter is used. The relay transmitter (fig. 7–8) consists of a 1-speed and a 36-speed synchro control transformer (*CT*), a commutator transmitter, a followup motor, and a reactor. These components are enclosed within a metal case provided for bulkhead mounting (fig. 7–8, A).

The relay transmitter is synchronized with the master compass by means of the synchro control transformer (fig. 7–8, B), followup motor, and relay-transmitter amplifier. The controlling signal voltage from the master compass energizes the primaries of the control transformers. The output of the control transformers is fed to the amplifier, the output of which controls the followup motor. The followup motor drives a commutator-type transmitter, the output of which energizes the repeaters, causing them to follow the master compass. The followup motor also drives the secondaries of the control transformers to the zero-voltage position, thereby synchronizing the relay transmitter with the master compass.

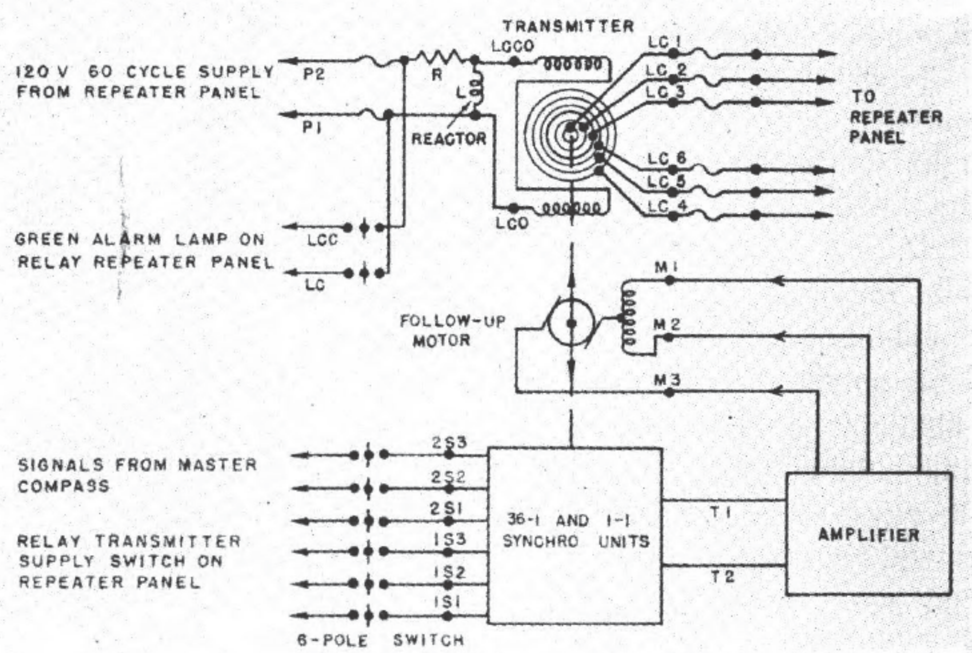
The commutator transmitter is essentially a stationary Gramme ring winding with taps, each of which is connected to a commutator segment. The 1-speed (outer) and the 36-speed (inner) set of commutator brushes are rotatable. They are concentrically mounted and bear on a flat stationary commutator. Each set comprises three brushes marked "blue," "green," and "red," respectively. Three commutator bars are similarly marked.

When the transmitter is on electrical zero, the blue brushes are in the center of the blue commutator bar. The "red" and "green" brushes on the 1-speed set are located 120° 20′ from the "blue" brush; whereas, the "red" and "green" brushes on the 36-speed set are located 119° 40′ from the "blue" brush.

The 1-speed and 36-speed commutator brushes are connected respectively to the concentrically mounted 1-speed



A. INTERNAL VIEW



B. SCHEMATIC DIAGRAM

Figure 7—8.—Sperry Mk XI Mod 6 gyrocompass relay transmitter.

and 36-speed slip rings. Each set comprises three slip rings with brushes that are connected to leads from the repeater panel.

In the operation of the commutator transmitter, the three voltages selected by each set of brushes correspond to the secondary output of a conventional-type synchro transmitter. However, the increase or decrease in the output voltage is not as smooth as in the conventional-type synchro, but occurs in steps that depend on the number of commutator bars and brushes used in the commutator transmitter. There are 360 commutator bars corresponding to 360° of rotation for the 1-speed circuit. Since there are three brush positions approximately 120° apart, three voltage steps will occur for each degree of rotation. A reactor, connected in shunt with the single-phase, 120-volt, 60-cycle input stabilizes the current supplied with varying load, thereby improving the performance of the commutator transmitter.

The six stator leads from the 1-speed and 36-speed master-compass transmitters (fig. 7–8, B) are fed to a terminal block in the relay transmitter and then through six poles of a 6-pole switch to the respective primaries (stators) of the 1-speed and 36-speed synchro control transformers. The voltages induced in the secondaries (rotors) of the control transformers are fed to the relay transmitter amplifier. The output of this amplifier drives the followup motor that causes the commutator transmitter to follow the master compass.

The single-phase, 120-volt, 60-cycle supply does not pass through the 8-pole switch, but is fed directly from the terminal block through two fuses to the reactor and commutator transmitter. However, the 120-volt supply to the pilot lamp is fed through two poles of this switch.

RELAY TRANSMITTER AMPLIFIER PANEL.—The relay transmitter amplifier panel (fig. 7–4) is located adjacent to the followup panel. It consists of a voltage amplifier and a power amplifier. A schematic of the relay trans-

mitter amplifier circuits is indicated in figure 7–9. The voltage amplifier, *V*1, receives the signal from the control transformers, and the output is fed to the power amplifier, *GR*1-*GR*2. The power amplifier provides the controlled power necessary to operate the followup motor in response to the signals from the voltage amplifier.

The VOLTAGE AMPLIFIER consists of twin triode V1A and V1B. The voltage induced in the secondaries (rotors) of the 1-speed and the 36-speed control transformers by a displacement between the master-compass transmitter and the commutator transmitter is fed to the voltage amplifier through the primary of the input transformer, *T*1. The magnitude of the signal voltage is controlled by potentiometer *P*3. The secondary of *T*1 supplies the grids of V1 through the phase shifting network, *C*4, *C*5, *R*9, and *R*10.

The POWER AMPLIFIER consists of thyratrons *GR*1 and *GR*2. The output of *V*1 is fed to the grids of *GR*1 and *GR*2 through *C*9 and *C*10. The output of *GR*1 and *GR*2 energizes the followup motor. The plate voltages of the thyratrons are derived from the same 60-cycle, 120-volt source that supplies the plates of the voltage amplifiers and the synchro control transformers.

With no signal applied to *T*1, the cathode bias on the grids of *V*1*A* and *V*1*B* limits the plate current to equal values in both sections of the twin triode. Thus, the currents in both halves of choke *L*1 are of equal magnitude. Because these currents flow in opposite directions (outside to center tap of choke), the net voltage drop across *L*1 is limited to a small d-c component, and no a-c signal component appears across *L*1. With no signal applied to the grids of *GR*1 and *GR*2, the a-c bias on the power amplifier tubes is such that the thyratron plate currents flow for a small part of the conducting half cycle. With equal currents in the two opposing fields of the followup motor, no torque is developed and the motor does not operate. Plate supply for all tubes in the amplifier is

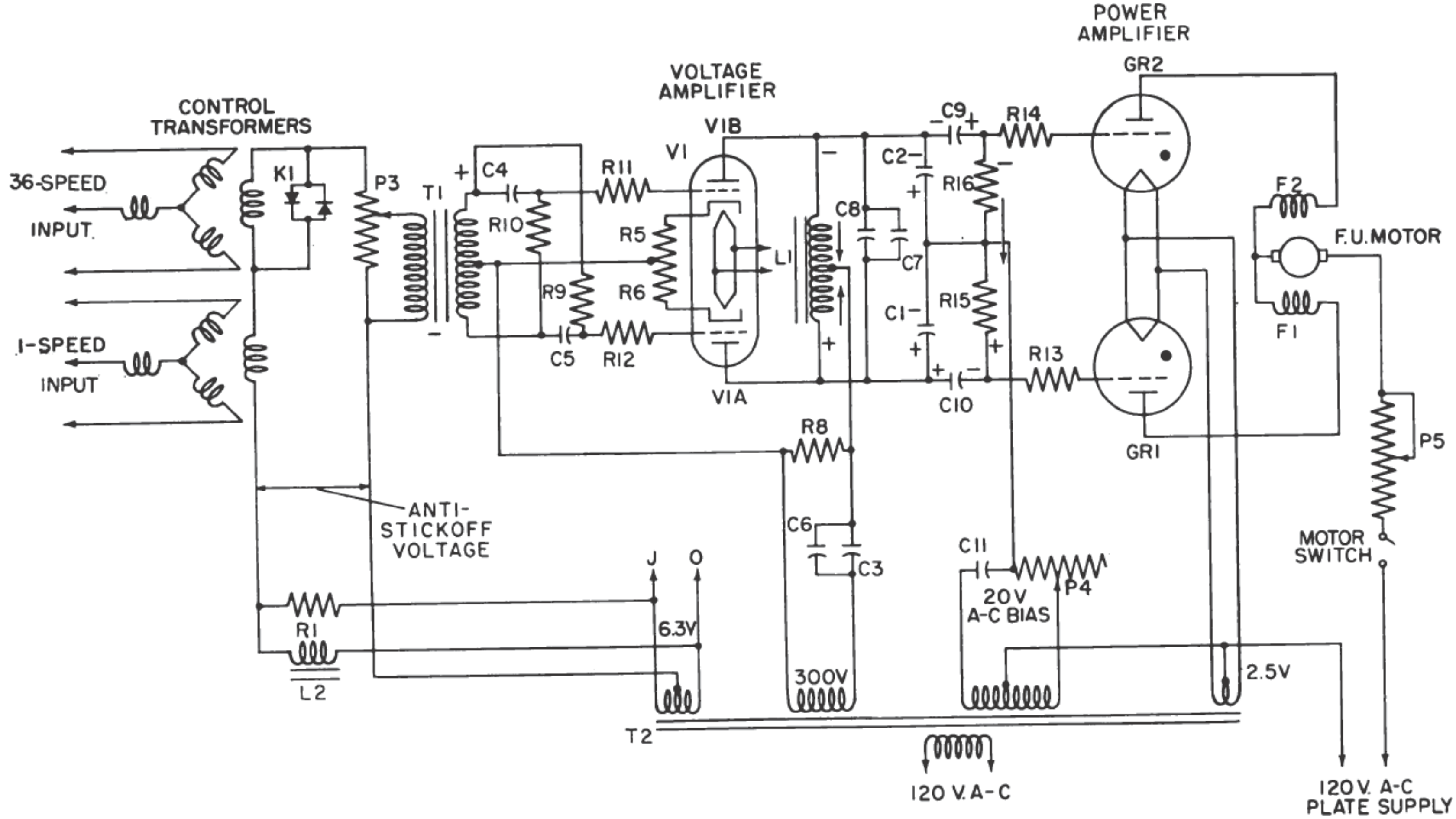


Figure 7—9.—Sperry Mk XI Mod 6 gyrocompass relay transmitter amplifier.

from the same a-c source so that plate currents flow in pulses during the half cycle that the plates are positive.

When a signal is applied to *T*1, an output signal is developed, and the followup motor operates to reduce the signal to zero, at which time the motor stops.

On the first half cycle of the applied signal, one grid of twin triode *V*1 is driven in a positive direction as the other grid is driven in a negative direction with respect to the common cathode. On the next half cycle, the polarities of the grids reverse, but this reversal can be disregarded because the plates of the amplifier tubes are negative at this time and no conduction occurs.

If an input signal is applied to *T*1 and is of a polarity such that the grid of *V*1*A* swings more negative and the grid of *V*1*B* swings more positive, the plate current of *V*1*A* will decrease, and that of *V*1*B* will increase. This action causes a potential difference to be set up across choke *L*1, the polarity of which is minus at the top and plus at the bottom. It is across *L*1 that the signal for the thyratrons is developed. The polarity of this signal depends on the half of *V*1 that is conducting more heavily.

In this case, section *V*1*B* will pass an increasing current through the upper half of *L*1, and section *V*1*A* will pass a decreasing current through the lower half of *L*1. The induced voltage across *L*1 makes the grid of *GR*2 more negative and the grid of *GR*1 more positive. This voltage also charges the rate capacitors *C*1, *C*2, *C*7, and *C*8. The polarities are indicated in the figure. The grid bias of *GR*1 will be reduced, and the grid bias of *GR*2 will be increased. Thus, *GR*1 passes a higher average current than *GR*2 because it conducts for a longer period during the conducting half cycle. Thus, the followup motor field, *F*1, will be stronger than field, *F*2, and the followup motor will drive the relay transmitter into alignment with the master compass.

The rate capacitors, *C*1, *C*2, *C*7, and *C*8, maintain the potential across the choke, *L*1, on alternate half cycles

when the plates of the tubes are negative by discharging through $L1$. As long as the potential exists across $L1$, the coupling capacitors, $C9$ and $C10$, cannot discharge. When the signal gradually decreases because of the relay transmitter approaching synchronism, the signal voltage across $L1$ also decreases, allowing $C9$ and $C10$ to discharge through $R15$ and $R16$ in the opposite direction to that of the signal voltage indicated by the arrow. This discharge provides a more negative bias for the controlling tube, $GR1$, and a more positive bias for the opposing tube, $GR2$. Hence, before the relay transmitter reaches synchronism, the controlling tube, $GR1$, is cut off, and the torque of the followup motor is reversed to prevent overtravel and hunting.

Normally, the controlling signal voltage for the relay transmitter is obtained from the 36-speed control transformer. The relay transmitter is made self-synchronous by properly combining the outputs of the 1-speed and the 36-speed control transformers. If the relay transmitter is more than 5° from the synchronous position, the voltage limiter, $K1$, limits the peak output voltage of the 36-speed control transformer so that the voltage of the 1-speed control transformer is greater and controls the amplifier. Conversely, if the relay transmitter is less than 5° from the synchronous position, the output voltage of the 36-speed control transformer is greater and controls the amplifier.

The voltage limiter, $K1$, consists of two copper oxide rectifiers connected in opposition and shunted across the secondary (rotor) of the 36-speed control transformer. The rectifiers offer nonlinear resistance with increasing voltage, that is, they offer almost no resistance to high voltages and a very high resistance to low voltages.

ANTISTICKOFF VOLTAGE.—A difficulty that must be overcome in a 2-speed system is the possibility that the system will lock in at 180° error angle. At this angle both the 1-speed and the 36-speed control transformer rotor voltages will be zero; the 36-speed rotor is a true zero

because it goes through a true zero every 10°. If the error angle is within 2.5° of the 180° position, the 36-speed control transformer is in control, causing the system to lag 180°. To prevent this condition from developing, the following circuits are used:

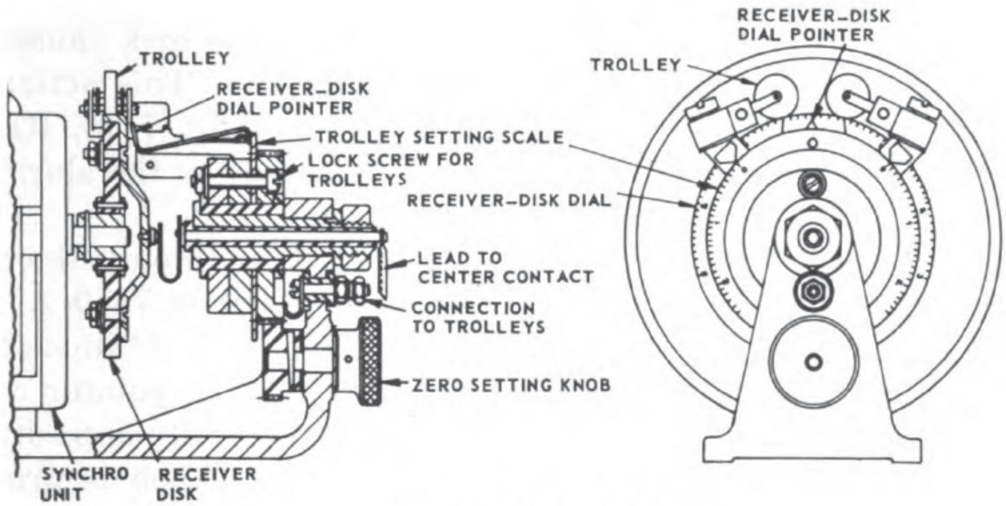
The 1-speed control transformer rotor is shifted so that a voltage equal to a 6° displacement (about 3 volts) is induced in the rotor winding when the system is at 0° or in correspondence with the master compass.

The network consisting of $L2$ and $R1$ is supplied by the 6.3 volt secondary of power transformer $T2$. This voltage (an antistickoff voltage of 3 volts) combines with the output voltage of the 1-speed control transformer to produce zero voltage at 0°. At the 180° position, the induced voltage of the 1-speed control transformer rotor will reverse its phase with respect to the antistickoff voltage so that the total voltage will be $3 + 3$ or 6 volts, and this signal will continue to drive the system beyond 180° to the true point of correspondence. The advantage of this system is that it will now have only one zero position instead of two.

DIFFERENTIAL ALARM RELAY.—The differential alarm relay (fig. 7–10) is a device for sounding an alarm whenever the relay transmitter loses synchronism with the master compass. The amount by which the transmitter is allowed to diverge, before the alarm is sounded, is adjustable from 0° to 2.5°.

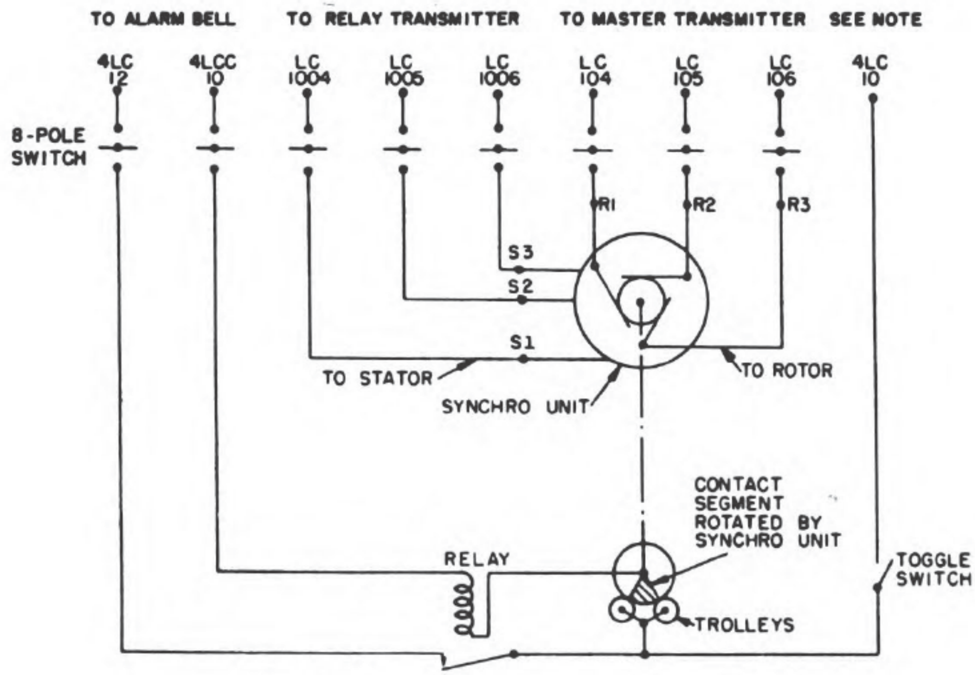
The device comprises a synchro differential receiver. The stator receives its signal from the 36-speed output of the relay transmitter; the rotor circuit receives its signal from the 36-speed transmitter at the master compass. As long as the two outputs are in agreement, the rotor remains at the neutral position. Failure of the relay transmitter to keep in synchronism causes the rotor to move from the neutral position to that amount corresponding to the divergence from synchronism.

A bakelite disk that has a metallic segment is mounted



CONTACT MECHANISM

A



NOTE: SUPPLY LEADS 4LC10 AND 4LCC10 FED TO RELAY TRANSMITTER REPEATER PANEL.

SCHEMATIC DIAGRAM

B

Figure 7—10.—Sperry Mk XI Mod 6 gyrocompass differential alarm relay.

on the shaft of the differential receiver (fig. 7–10, A). Two trolleys bear on the periphery of the disk. These trolleys are arranged so that rotation of the disk causes one trolley to contact the metallic segment. This action closes the 120-volt, a-c circuit to a relay (fig. 7–10, B), which in turn, closes the 120-volt, a-c supply to the alarm bells located in the pilot house (fig. 7–7).

A dial on the differential-receiver disk (mounted on the shaft) indicates the position of the rotor (fig. 7–10, A). This dial is graduated in 0.1° steps from 0° to 3° in each direction from the 0° position. The dial pointer is mounted on the trolley assembly and is normally opposite the zero mark on the dial. A zero-setting knob is provided for setting the trolley assembly on the zero position with respect to the dial.

The two trolleys can be set independently to allow for a divergence up to 2.5° before the alarm is sounded. Each trolley support has a pointer that is read against a trolley setting scale (fig. 7–10, A). When the pointer is opposite the zero mark on this scale, the trolley makes contact with the edge of the metallic segment (assuming the receiver disk is in the neutral position). This position corresponds to the position of no permissible divergence. Normally, the trolley is set back on its scale to allow a predetermined divergence.

An 8-pole switch on the relay transmitter repeater panel is provided for disconnecting the differential synchro receiver and the alarm circuit (fig. 7–10, B). The toggle switch disconnects only the alarm circuit.

ARMA MK VIII MOD 3A GYROCOMPASS EQUIPMENT

Control System

It is the purpose of this section of the chapter to explain, through the use of schematic diagrams, the function and operation of circuits used in the Arma compass equipment. For explanation by schematics, the circuits have been divided into groups as follows:

Figure 7-11.—Arma Mk VIII Mod 3A gyrocompass drive and speed control system.

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1. Gyro-drive and speed-control mechanism
2. Followup systems
3. Transmission system
4. Alarm system
5. Transfer switching system

The Arma Mk VIII Mod 3A gyrocompass control system (fig. 7–11) consists of a motor-generator, a speed-control mechanism, and a control panel, with the necessary apparatus for the operation and control of the master compass. The motor-generator switch on the control panel connects the ship's 3-phase supply to one of the two motor-generators that delivers 3-phase, 120-volt, variable-frequency power to drive the gyro rotors.

MOTOR-GENERATOR. — Two complete motor-generator sets are provided with each complete Arma gyrocompass equipment. Each motor-generator set consists of an induction motor and an a-c generator mounted on a common shaft, enclosed within a drip-proof housing, and mounted on a single bedplate.

The INDUCTION MOTOR is a 3-phase, 120-volt, 60-cycle, wound-rotor motor with slip rings. The speed is controlled by means of a rheostat in the rotor circuit. The rheostat is driven by a reversible single-phase motor having two stator windings spaced 90° apart.

The A-C GENERATOR is a 3-phase, 120-volt, 205-cycle separately excited generator. The d-c voltage necessary to excite the generator field is obtained through the control panel from a high vacuum electron tube rectifier mounted on the followup panel. This rectifier converts the ship's single-phase, 120-volt supply to direct current at 120 volts.

SPEED-CONTROL MECHANISM.—As explained in the training course, *I.C. Electrician 2,* NavPers 10556, it is necessary to change the speed of the two gyro rotors in the Arma compass with changes in the ship's latitude in order to avoid a temporary ballistic deflection error on changes in ship's speed or course. The speed of the gyro-

compass rotors is varied by varying the speed of the motor-generator set. This is accomplished by means of a single-phase reversible motor that drives a rheostat inserted in the rotor circuit of the motor-generator set.

The speed control mechanism is arranged to automatically maintain the speed of the induction motor constant for any given latitude independent of variations in the ship's supply voltage and frequency. This action is accomplished by means of the electro mechanical speed control loop indicated in figure 7–12. Also this mechanism provides for manually changing the speeds of the gyro rotors to correspond with the latitude in which the compass is operating.

The correct gyro rotor speed is obtained by turning the latitude dial on the control panel until it indicates the ship's latitude (fig. 7–11). The dial is directly connected to a variable inductance *L*2, which is in a series resonant circuit containing *C*1, energized from one phase of the gyro rotor supply. Once this dial is set, the speed control mechanism holds the speed constant at the value corresponding to the dial setting.

Normally, *L*2 and *C*1 are in series resonance, and short circuit winding *B* of the reversible motor so that it will not operate. Resistor *R*1 prevents the series resonant circuit from short circuiting the gyro supply. As long as *C*1 and *L*2 are series resonant, only winding *A* of the motor is active, and no starting torque is developed.

If the ship's supply voltage and frequency drop below normal, the induction motor decelerates, and the frequency of the gyrocompass supply voltage fed to *C*1-*L*2 decreases. This action increases the capacitive resistance of *C*1 and decreases the inductive reactance of *L*2, thereby effectively removing the short circuit from winding *B* of the reversible rheostat-drive motor and shunting the winding with a capacitor. Since winding *A* is shunted with a resistor, there is approximately a 90° phase shift between the currents in windings A and B. A rotating

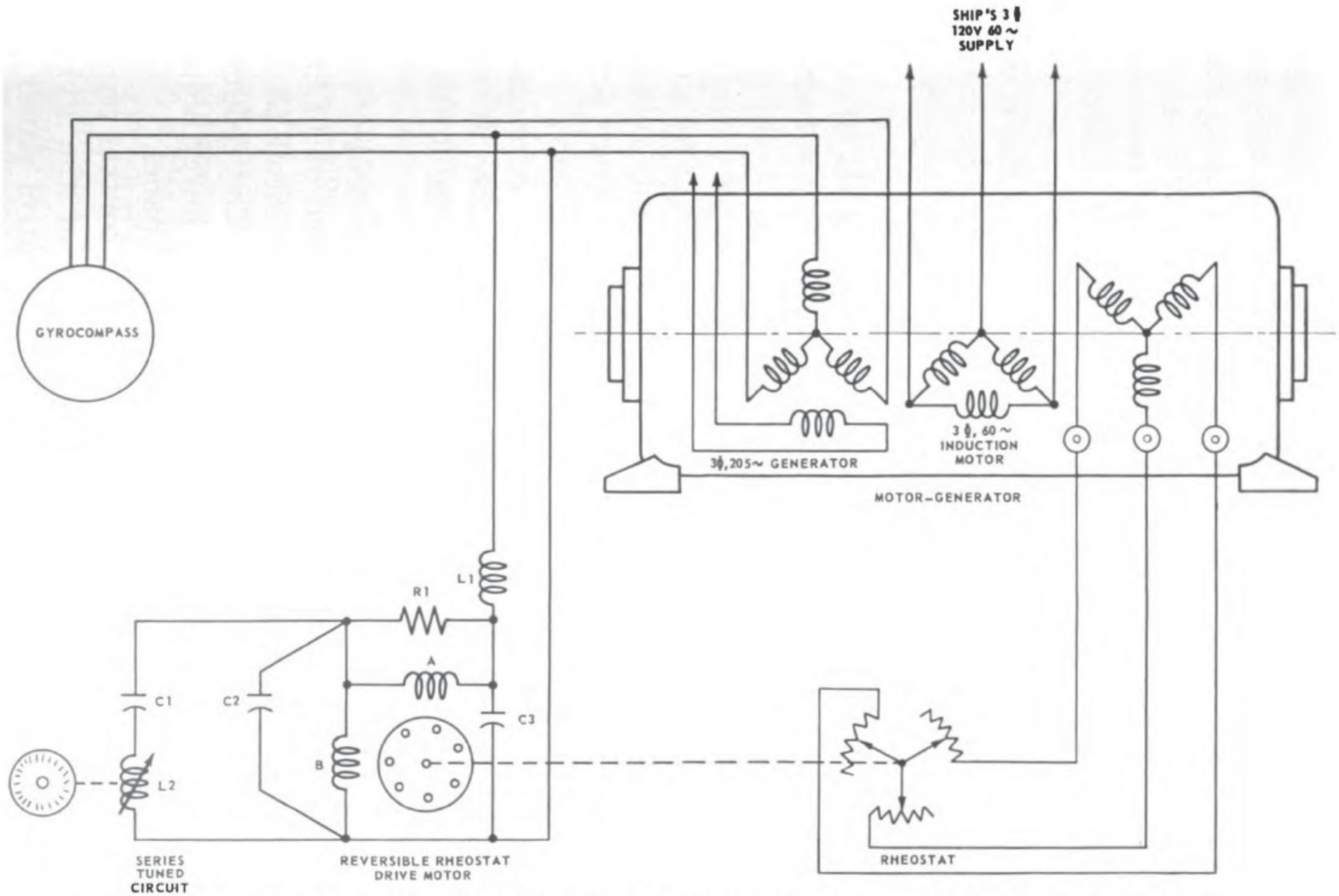


Figure 7—12.—Arma Mk VIII Mod 3A simplified gyrocompass drive and speed control mechanism.

field is produced that accelerates the motor, causing it to drive the rheostat in a direction to lower the resistance in the rotor circuit of the 3-phase induction motor of the gyrocompass motor-generator set. This action increases the rotor currents and decreases the rotor slip, thereby restoring almost instantly the speed of the induction motor and the generator frequency to their normal values. This action also restores the *C*1-*L*2 circuit to the resonant frequency, thereby reducing the voltage on winding B of the rheostat-drive motor, causing it to stop.

Capacitor C2 is shunted across winding B of the rheostat-drive motor to reduce the effect of the series resonant circuit C1-L2 on winding B to that of a partial short circuit.

Capacitor *C*3 is shunted across the terminals of the rheostat-drive motor to improve the motor power factor and decrease the current drawn from the gyro supply. Inductor *L*1 is an air-core choke inserted in series with the input to the motor in order to keep a uniform voltage applied to the motor terminals. When the supply voltage is high, the frequency is also high, and the voltage drop across *L*1 compensates for the higher supply voltage.

The single-phase rheostat-drive motor is connected through a reduction gear and friction clutch to the speed-control rheostat in the rotor circuit of the 3-phase induction motor.

At the equator, the frequency of the a-c generator is a maximum of 190 cycles for a gyro rotor speed of 11,290 rpm. At 70° latitude, the frequency is reduced to 68 cycles for a gyro rotor speed of 4,060 rpm. The reduced generator speed at high latitudes results in a lower meter indication of the gyro voltage on the control panel.

COMPASS CONTROL PANEL.—The compass control panel is located at the upper left-hand section of the gyrocompass switchboard (fig. 7–13). The control panel is used to indicate the operating conditions of the master compass. The ship's 3-phase, 120-volt, 60-cycle power

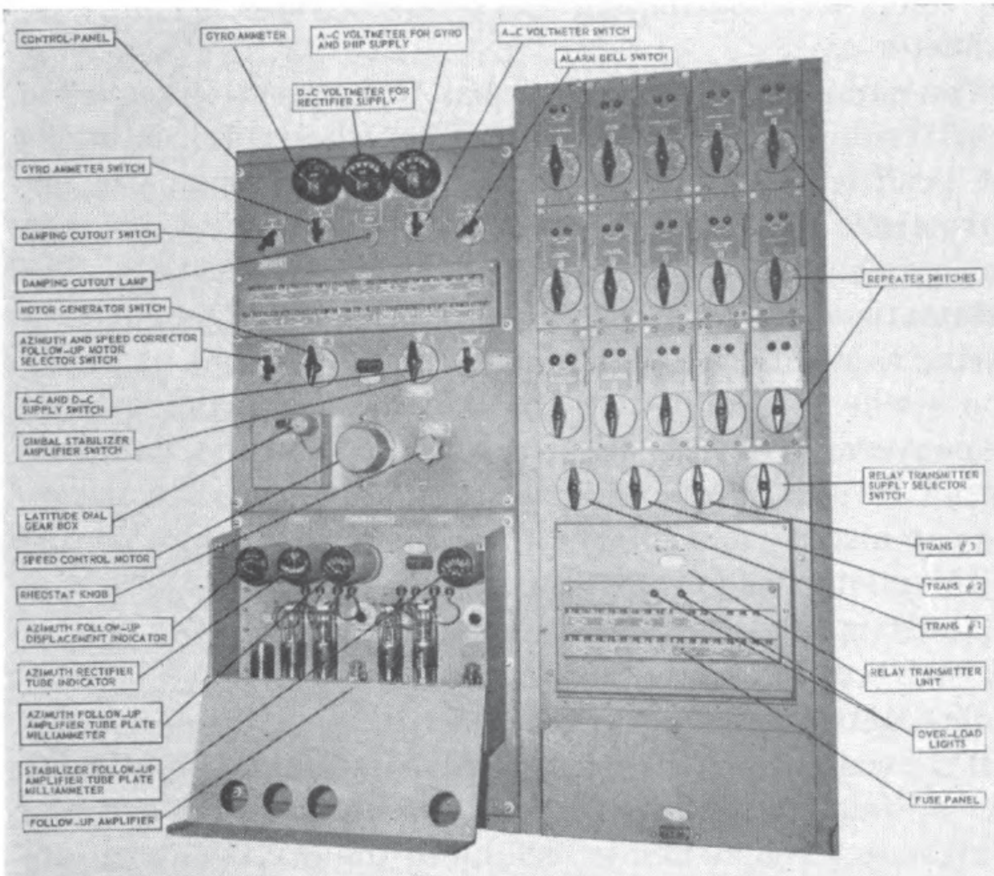


Figure 7—13.—Arma Mk VIII Mod 3A gyrocompass switchboard.

supply and the ship's single-phase, 120-volt, 60-cycle power supply are connected directly to this panel.

An a-c ammeter, a d-c voltmeter, and an a-c voltmeter are mounted at the top of the control panel. The ammeter indicates the current in each phase of the circuit to the gyro rotors. The phases are selected by means of a rotary switch located directly below the ammeter. The d-c voltmeter indicates the voltage supplied by the rectifier for the generator field. The a-c voltmeter indicates the (1) ship's 3-phase, 60-cycle power supply, (2) ship's single-phase, 60-cycle power supply, and (3) variable-frequency gyro power supply. These voltages are selected by means of a rotary switch located directly below the a-c voltmeter. The damping cutout switch, damping cut-

out lamp, and alarm-bell switch are mounted below the ammeter.

The damping cutout switch has three positions marked "on," "automatic," and "off." When the switch is in the ON position, continuous damping is obtained. In the AUTOMATIC position, the damping cutout valve is open except when the automatic switches are operated. The automatic switches operate during prolonged fast turns or during rapid changes in the ship's speed. In the OFF position (when ordered by the navigator during abrupt maneuvers to avoid the damping error), the damping cutout valve is closed to cut out the damping. The damping can also be shut off by means of pushswitches located in the pilot house or conning tower.

The damping cutout lamp is energized when the flow of oil between the damping tanks is cut off.

The alarm selector switch has six positions marked "off", "normal," "60 cycles," "205 cycles," "azimuth followup," and "stabilizer followup." The last four are test positions. The switch is usually in the NORMAL position. When trouble occurs in the line voltage or followup systems the alarm bell rings. The trouble is located by turning the selector switch (to the various test positions) until the position is reached that silences the alarm bell.

The fuses for the protection of the various circuits are located on the control panel below the first row of switches.

The second row of switches located below the fuse panel include the azimuth and speed correction switch, the motor-generator switch, the a-c and d-c supply switch, and the gimbal stabilizer amplifier switch.

The azimuth and speed correction switch controls the automatic speed corrector motor and the azimuth followup motor. It has three positions marked "off," "azimuth only," and "azimuth and speed corrector." When this switch is in the AZIMUTH ONLY position, the automatic speed corrector is disconnected and the speed corrector

mechanism can be operated manually. However, the azimuth followup system continues to function.

The motor-generator switch controls the power supply to the gyro drive. It has three positions marked "off," "motor-generator 1," and "motor-generator 2." When the switch is turned to select one of the two motor-generators, a thermostatic time delay relay keeps the generator field disconnected until the motor comes up to speed, at which time the field is cut in, and the generator carries the gyro load.

The a-c and d-c supply switch provides a means of supplying the ship's 3-phase and single-phase power to the gyrocompass system. It has five positions marked "off," "a-c only," "a-c and forward d-c," "a-c only," and "a-c and after d-c." This switch is arranged so that the d-c supply can be obtained from the rectifier on either the forward or the after control panels. TWO A-C ONLY positions are provided so that the rectifier tube filaments (on the followup panel) can be heated before the plate potential is applied by turning the switch to the A-C and D-C position. Hence, one of the A-C ONLY positions must be passed before selecting the forward or after d-c supply.

The gimbal stabilizer amplifier switch is provided for turning on or off the gimbal stabilizer amplifier. When the compass is used only for navigation, this switch is in the OFF position. When the compass is used for fire control requiring extreme accuracy, it is in the ON position.

The speed control mechanism and motor-generator rheostat are located at the bottom of the control panel.

The speed control mechanism consists of a graduated dial provided with a knob for manually setting the latitude to provide the correct rotor speed for each latitude.

The motor-generator rheostat is fitted with a handle for cutting out the resistance when the gyros are started so that the generator can come up to speed. Otherwise, if the resistance is left in when the generator switch is thrown, the generator might not come up to speed and

supply sufficient voltage to operate the speed control mechanism.

DAMPING CUTOUT PUSHSWITCH.—Damping cutout pushswitches are installed in the pilot house and secondary conning station. They provide a means of controlling the damping at these locations in addition to the control panel. This pushswitch is provided for bulkhead mounting.

Followup System

The Arma Mk VIII Mod 3A gyrocompass followup system comprises the azimuth and gimbal stabilization followup mechanisms (previously described with the master compass in the training course, *I.C. Electrician 2*), the followup panel, and the speed acceleration damping cutout unit. The primary function of the followup system, which is similar to the Sperry system, is to drive the spider of the master compass in azimuth. When the ship changes course, the spider turns with it and away from the sensitive element. Thus, the spider must be driven at the same rate in the reverse direction to aline it with the sensitive element.

FOLLOWUP PANEL.—The followup panel (fig. 7–13) is located below the compass control panel. It includes a voltage amplifier, power amplifier, and antihunt unit. The voltage amplifier receives the signals from the followup transformers on the master compass and the output is fed to the power amplifier. The power amplifier provides the controlled power necessary to operate the azimuth and gimbal stabilization followup motors in response to the signals from the voltage amplifier.

The azimuth and gimbal stabilization followup and damping cutout circuits are illustrated by the schematic diagram in figure 7–14. These circuits include the damping cutout valve (on the master compass) and the speed acceleration damping cutout unit (on the followup panel), and the azimuth and gimbal stabilization followup transformers and motors.

SPEED ACCELERATION DAMPING CUTOUT UNIT.—The automatic damping eliminator circuit (fig. 7–14) includes the (1) rate of turn switch, (2) amount of turn switch, and (3) speed acceleration damping cutout unit.

The centrifugally operated rate of turn switch (described with the master compass in the training course, *I. C. Electrician* 2) is mounted on the azimuth followup

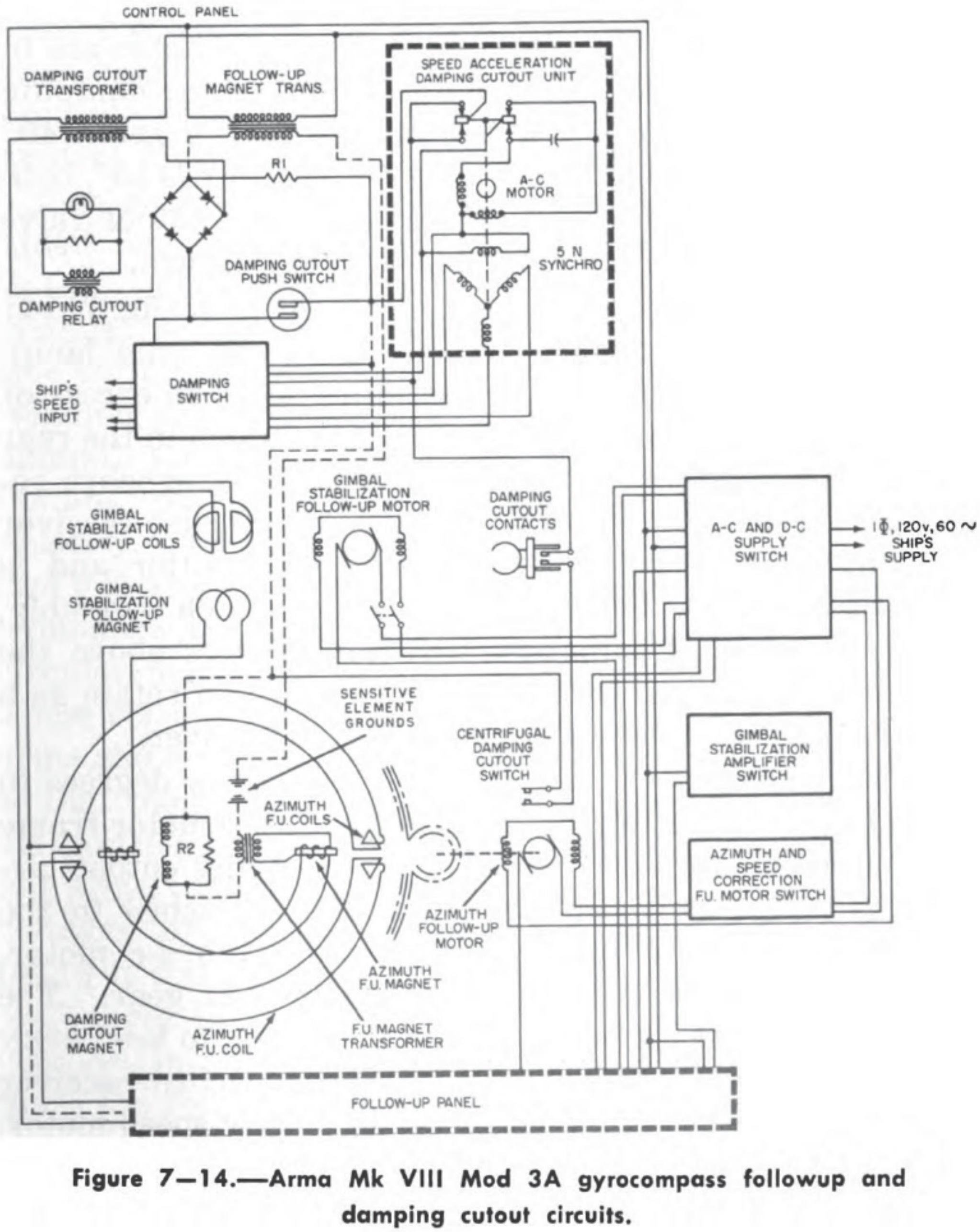


Figure 7—14.—Arma Mk VIII Mod 3A gyrocompass followup and damping cutout circuits.

motor shaft. This switch closes a set of contacts to operate the damping cutout valve when the rate of change in the ship's course exceeds 40° per minute. The amount of turn switch, mounted on the top of the ordance transmitter is a lost-motion device driven by the 1-speed synchro transmitter brush shaft. When the amount of change in the ship's course exceeds 15°, this switch closes another set of contacts to operate the damping cutout valve.

The rate of turn and the amount of turn switches are in series, and both must be closed to complete the damping eliminator circuit. When the rate of turn exceeds 40° per minute and when the amount of turn exceeds 15°, both sets of contacts are closed and the damping cutout valve is operated to eliminate damping during the turn.

The speed acceleration damping cutout unit (fig. 7–14) also operates the damping cutout valve to eliminate damping during rapid changes in the ship's speed in excess of about 2 knots per minute. This unit, mounted in the rear of the followup panel, consists of a type-5N synchro receiver and a slow-speed a-c motor. The synchro receiver is connected to the underwater log transmitter and is geared to the a-c motor through a slip clutch assembly. The a-c motor is supported on ball bearings above the synchro receiver so that the entire motor can rotate as a unit about the center line of the synchro receiver.

When the motor is rotated more than a few degrees in either direction, contact arms attached to the motor frame will close contacts connected to the damping cutout circuit. At the same time, contact arms attached to the motor frame close contacts to energize the a-c motor, causing it to turn about the synchro-receiver gear. The motor always turns in a direction that tends to keep OPEN the damping cutout contacts. If the synchro receiver turns at a higher rate of speed than the slow-speed motor, the synchro receiver will close the damping cutout contacts to eliminate damping during the rapid change in

speed. When the ship's speed becomes steady, the synchro receiver stops and the motor opens the damping cutout contacts to apply damping. This action simultaneously opens the contacts in the a-c supply to deenergize the a-c motor.

FOLLOWUP TRANSFORMERS.—Two azimuth followup transformers are provided, each consisting of one primary and two secondaries (fig. 7–14). The primaries (followup magnets) are mounted on opposite sides of the sensitive element. The secondaries (followup coils), each consisting of two coils in series, are mounted on opposite sides of the followup ring (attached to the spider) directly opposite its associated primary.

One gimbal stabilization followup transformer is provided, consisting of one primary and two secondaries (fig. 7–14). The primary (followup magnet) is a horizontal, channel-section circular magnet mounted on top of, and in line with, the vertical axis of the sensitive element. The winding is energized from the same a-c supply as the azimuth followup magnets and is such that at any given instant, the inside and outside rings are of opposite polarity. The secondary (followup coils) consisting of two D-shaped coils in series, is mounted directly over the primary with the straight sides of the coils tangent to the circular magnet (primary) in a fore and aft direction. These coils are mounted inside the azimuth followup coil arms and are fastened to a differentially geared platform so that their straight sides are maintained in a fore and aft position, irrespective of the rotation of the azimuth coil arms. Slip rings on this platform transmit the coil voltages through a double set of brushes on the azimuth followup coil arms to a set of stationary slip rings.

Changes in the ship's course produce no unbalanced voltages in the gimbal stabilization followup coils because the followup circular magnet is symmetrical about the axis of the sensitive element. Also, when the ship pitches, the gimbal sway in a fore and aft direction

causes the circular magnet to move parallel with the straight sides of the D-shaped followup coils, and no unbalanced voltages are produced in these coils. However, when the ship rolls, the relative motion between the sensitive element and the followup circular magnet produces unbalanced voltages in the followup coils because one coil moves away from, and the other coil remains over, the magnet.

The primaries of the azimuth and gimbal stabilization followup transformers and the damping cutout valve (on the sensitive element) are energized respectively from a followup magnet transformer and a damping cutout transformer mounted on the back of the control panel (fig. 7–14).

The damping cutout transformer primary is supplied from the ship's single-phase, 120-volt, 60-cycle power. The secondary of this transformer is connected to a full-wave rectifier to supply direct current to the damping cutout valve. A damping cutout relay in this circuit lights a lamp on the control panel to indicate when the damping is inoperative. Direct current is supplied to the damping cutout magnet through two transformer windings and the sensitive-element ground.

The followup magnet transformer primary is connected to the same ship's single-phase power in parallel with the primary of the damping cutout transformer. Alternating current for the azimuth and gimbal stabilization followup magnets is supplied to a transformer on the sensitive element through resistors *R*1 and *R*2. The resistors shunt the rectifier and the damping cutout magnet, and the transformer keeps direct current out of the followup magnets.

The secondaries of the azimuth and gimbal stabilization followup transformers are connected in series opposing, so that the induced voltages are 180° out of phase.

OPERATION OF FOLLOW-UP AMPLIFIERS.—The following description of the followup circuits applies to both the

azimuth and gimbal stabilization systems, a simplified diagram of the Arma Mk VIII Mod 3A gyrocompass azimuth followup amplifier is indicated in figure 7–15. It includes a voltage amplifier and a power amplifier. The output of the power amplifier supplies the followup motor which drives the spider of the master compass in azimuth to aline it with the sensitive element. This motor is a quarter horsepower commutator-type reversible shunt motor with the field supplied from the ship's 120-volt, d-c supply.

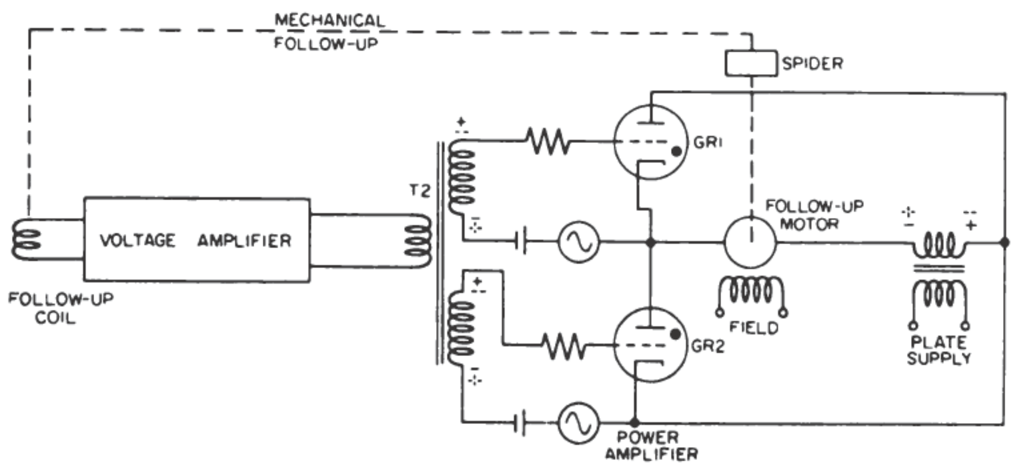


Figure 7—15.—Arma Mk VIII Mod 3A gyrocompass azimuth followup amplifier.

The followup action of the spider is as follows.

1. A change in the ship's heading causes a slight movement of the followup coil in relation to the followup magnets on the sensitive element.
2. The shift of the followup coil develops a voltage across its leads.
3. This voltage is greatly magnified by the voltage amplifier.
4. This amplified voltage is applied to the grids of GR1 and GR2.
5. The phase of the voltage is, for example, such as to cut off GR2.

6. GR1 supplies a current through the followup motor armature, causing it to aline the spider of the master compass in azimuth with the sensitive element. When alinement occurs, the input signal ceases and the followup motor stops.

A schematic diagram of the Arma Mk VIII Mod 3A gyrocompass azimuth followup system is indicated in figure 7–16. The VOLTAGE AMPLIFIER consists of twin triode V1 that functions as a two stage amplifier. The signal voltage from the followup transformer is fed through slip rings to the input transformer, T1. The secondary of T1 supplies the grid of V1A. The phase of the signal voltage applied between grid and cathode of V1A is shifted by means of R14 and C7 in order to properly combine the output voltage across T2 with the other voltage in the power amplifier grid circuits. The output of section V1A is developed across R15 and is coupled to section V1B through C8 and P1. The magnitude of the signal voltage is controlled by P1. Plate voltage for both triode sections is obtained from power supply transformer T8. This voltage is rectified in CR3 and filtered by L1, L3, C14, and C15. Cathode bias is developed across R24.

The POWER AMPLIFIER consists of thyratrons, GR1 and GR2. The output of V1 is coupled to GR1 and GR2 by means of the interstage transformer, T2. The primary of T2 includes the plate-current milliammeter, M3, and a relay. The relay operates to sound an alarm when a displacement of slightly more than ½° occurs between the followup coil and the sensitive element to indicate failure of the followup system.

The interstage transformer, *T*2, has three secondaries. The upper secondary supplies the grid of *GR*1. The middle secondary supplies the grid of *GR*2. The lower secondary supplies the tube indicator, a visual device that indicates which tube is firing and which one is not firing. The grid circuits of *GR*1 and *GR*2 are identical. The

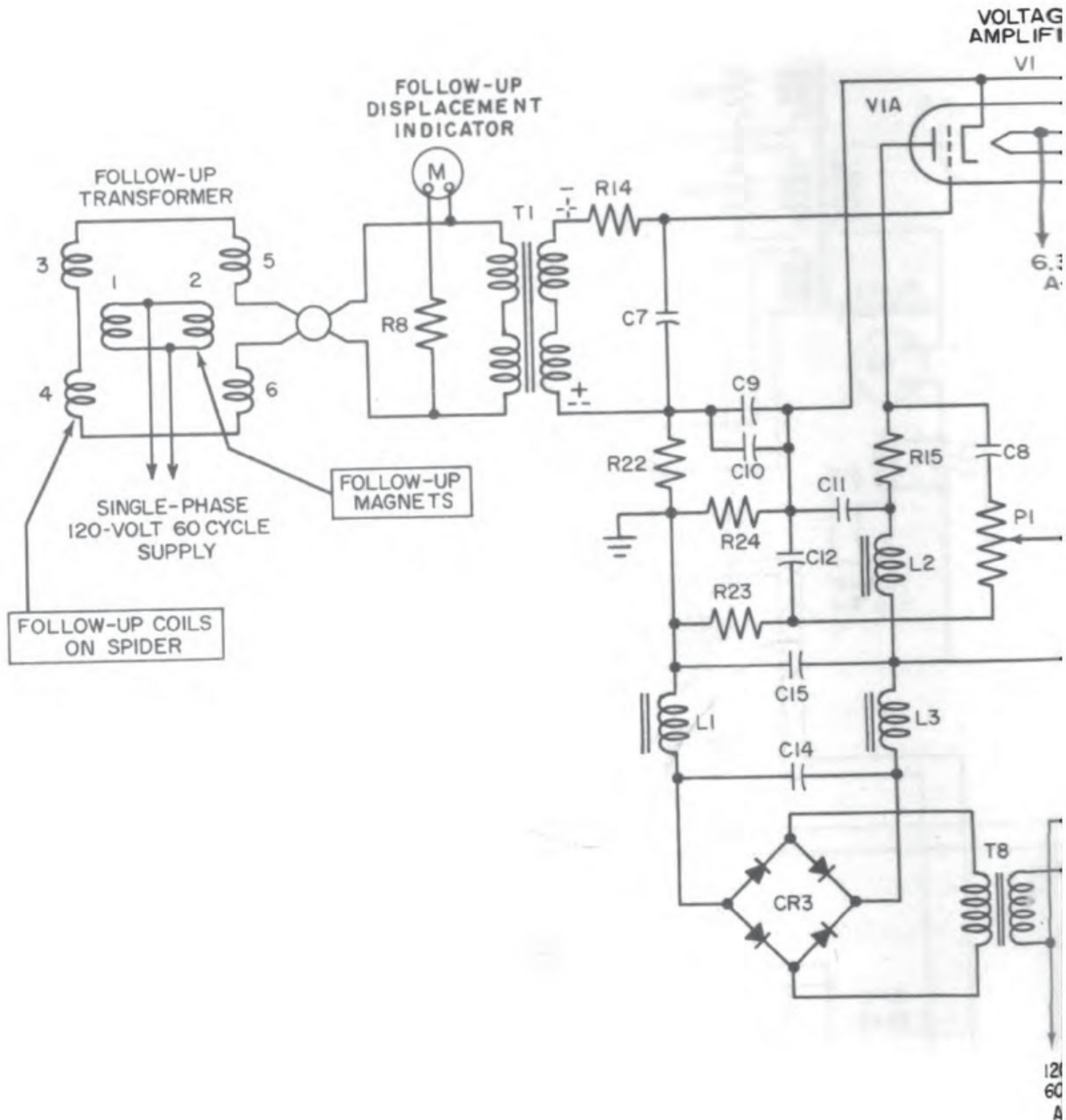


Figure 7-16.—Arma Mk VIII Mod 3A

plate circuits of *GR*1 and *GR*2 are also identical, except that their plate voltages are 180° out of phase.

Both a-c and d-c grid biases are used in the power amplifier stage. A-c bias is provided by *T*4. D-c bias is provided by *T*6 and rectifiers *CR*1 and *CR*2. The d-c output of *CR*1 is filtered by *R*27, *R*20, and *C*20. The output of *CR*2 is filtered by *R*28, *R*21, and *C*21. Plate power is supplied by a secondary of *T*5 in series with the armature of the followup motor.

When the spider and sensitive elements are alined, the followup magnets are centrally located with respect to the associated followup coils (fig. 7–16). The voltages induced in the followup coils are equal and opposite, and the resultant voltage across the output terminals of the followup transformer is zero. With no signal developed across *T*1 or *T*2, a limited amount of conduction occurs in *GR*1 and *GR*2 for equal portions of alternate half cycles, and the alternating current flowing through the followup motor armature develops no motor torque.

This action keeps the rectifier tubes warmed up at all times and in readiness to respond to a signal.

When the followup coils are displaced from the neutral position line in ONE direction (fig. 7–16), followup coils ③ and ⑥ will be opposite followup magnets ① and ②. Thus, the voltage induced in followup coils ④ and ⑤ is smaller than the voltage induced in followup coils ③ and ⑥, and the resultant voltage across the output terminals of the followup transformer is the difference between these voltages. This signal voltage is amplified in *V*1*A* and *V*1*B* and applied the primary of *T*2.

The signal is induced in the secondaries of *T*2 and applied to the grids of *GR*1 and *GR*2. If both grid leads are positive, for example, at the same time that the plate of *GR*1 is positive, *GR*1 will conduct. During this half cycle, *GR*2 will not conduct because its plate is negative (fig. 7–15). On the negative half cycle of the input signal, *GR*1 will not conduct because its plate is negative.

Although the plate of *GR*2 is positive during this half cycle, the grid of *GR*2 is negative, hence *GR*2 does not conduct. Therefore, the applied signal in this example increases the current in the plate circuit of *GR*1 and decreases the plate current in GR2. The resultant current in the followup motor armature predominates in one direction with the result that the motor develops a torque that drives the azimuth ring into alinement with the sensitive element on the master compass, thereby reducing the input signal to the amplifier to zero. At this time the plate currents of GR1 and GR2 equalize and the motor stops.

When the followup coils are displaced from the neutral position in the OTHER direction (fig. 7–16), followup coils ④ and ⑤ will be opposite followup magnets ① and ②. The voltage induced in followup coils ③ and ⑥ is smaller than the voltage induced in followup coils ④ and ⑤, and the resultant voltage across the output terminals of the followup transformer is the difference between these voltages. If the input signal applied to *T*2 reverses its phase with respect to the alternating voltage applied to the plates of *GR*1 and *GR*2, both grid leads will be positive at the same time that the plate of *GR*2 is positive. Plate current increases in *GR*2 and decreases in *GR*1 on alternate half cycles, and current flow through the armature of the followup motor predominates in a direction that is opposite to the direction established for the previous signal.

The proper operation of *GR*1 and *GR*2 is indicated by an azimuth rectifier tube indicator. This indicator is a central-zero electrodynamometer type of galvanometer with one winding connected across the single-phase supply and the other winding connected to the third secondary of interstage transformer, *T*2. If the azimuth followup coil is displaced to a reading on the compass card below or above the correct value, for example, the power amplifier circuit is such that *GR*1 operates to increase

and *GR*2 operates to decrease, the card readings indicate the fact as "tube 1 on"—"tube 2 off."

Displacement of the followup coils in the opposite direction causes *GR*2 to conduct and *GR*1 to stop conducting, and the indicator reads, "tube 2 on—tube 1 off." Hence, tube failure is indicated, for example, when the indicator reads "tube 1 on—tube 2 off," and tube 1 shows no evidence of gas ionization.

The ANTIHUNT UNIT (fig. 7–16) is provided in the followup circuit to obtain positive control of the oscillation, or hunting of the followup mechanism.

The sensitivity of the followup circuit is adjusted by changing the amplification ratio of the power amplifier. If the sensitivity (amplification) is low, the followup coils must be appreciably displaced from the neutral position before the signal voltage is sufficient to fire the thyratron tube and operate the followup motor. On the other hand, if the sensitivity is high, the displacement (dead space) between the followup coils and the followup magnet is appreciably reduced, resulting in continued hunting of the followup mechanism.

Hunting can be eliminated even when the dead space is reduced to a very small value by means of the antihunt circuit. The antihunt circuit introduces a signal that provides a negative bias for the tube that is conducting and a positive bias for the tube that is not conducting. Hence, just before the point of synchronism is reached, the conducting tube is cutoff, and the other tube will conduct, thereby reversing the torque of the followup motor and preventing over travel or hunting.

The current through the armature of the followup motor is a pulsating direct current, flowing in one direction and then in the other. The magnitude and direction of this current depends on the amount and direction of displacement of the followup coils. Over a period of several oscillations, this pulsating direct current has the characteristics of a low-frequency alternating current, the fre-

quency of which is the same as the oscillations of the hunting spider.

This low-frequency alternating current produces an a-c voltage drop across *R*12 that is impressed on the primary of transformer *T7A* in the antihunt unit (fig. 7–16). The phase of the voltage induced in the secondary of *T7A* is shifted nearly 90° by means of *C*22 and *R*11 before it is impressed on the primary of transformer *T7B*, also in the antihunt unit. The secondaries of *T7B* are connected to the grids of *GR*1 and *GR*2 by means of *C*18, *C*19, *R*18, and *R*19, so that the antihunt voltage on the two grids is 180° out of phase. The antihunt voltage applied to the grids of *GR*1 and *GR*2 leads the motion of the followup coils by nearly 90°. This phase shift places the antihunt voltage in the proper phase relation with respect to the signal voltage of *T*2. As the followup coils approach the neutral position, the effect is to increase the negative bias on the operating tube and to decrease the negative bias on the other tube. This action reverses the torque of the followup motor just before the neutral position is reached, thereby preventing overtravel and hunting.

Alarm System

The Arma Mk VIII Mod 3A gyrocompass alarm system (fig. 7–17) includes the alarm bells with three-drop annunciators and the relays necessary to indicate failure of the followup systems or of the ship's power supply.

ALARM BELL WITH ANNUNCIATOR.—The alarm bell with annunciator is installed in the pilot house and other strategic locations to provide an audible and visual signal in the event of power failure or trouble in the followup systems. The annunciator has three drops, two of which are marked A and F to denote trouble in the after or forward equipments respectively. The third annunciator drop is a spare. The bell and annunciator are provided for bulkhead mounting and are installed as a unit.

ALARM RELAYS.—The alarm relays (fig. 7–17) are provided in the 60-cycle power supply, the 205-cycle power

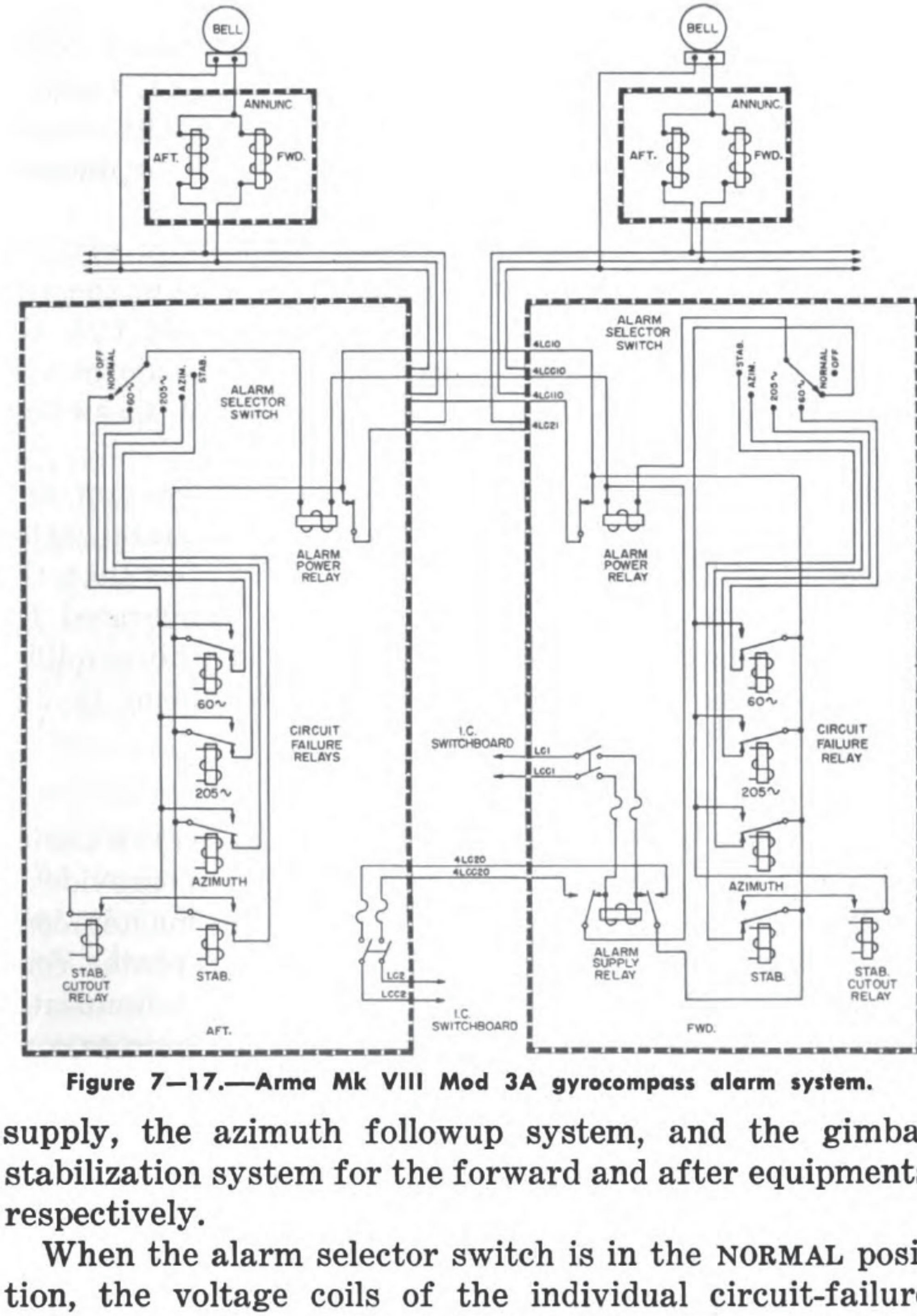


Figure 7—17.—Arma Mk VIII Mod 3A gyrocompass alarm system.

supply, the azimuth followup system, and the gimbal stabilization system for the forward and after equipments respectively.

When the alarm selector switch is in the NORMAL position, the voltage coils of the individual circuit-failure relays are energized to hold OPEN the alarm contacts. Turning the alarm selector switch through the four test positions causes the circuit-failure relays to actuate an alarm power relay that operates the numerous alarm bells and annunciators in the system.

In the event of failure of the 60-cycle power supply, the sensitive relay in this circuit is deenergized to close the alarm contact and energize the alarm power relay to sound the alarm bell. Turning the alarm selector switch to the 60-cycle test position silences the bell to indicate that the trouble is in this circuit.

The alarm bell and annunciators are normally supplied with single-phase, 120-volt, 60-cycle power from the forward I. C. switchboard. If this supply should fail, the alarm supply relay releases and energizes the alarm system with single-phase power from the after I. C. switchboard.

STABILIZATION CUTOUT RELAY.—The stabilization cutout relay (fig. 7–17) is provided to open the stabilization alarm circuit. This provision is necessary so that the stabilizer unit on the control panel can be operated for making tests, adjustments, or warming up the amplifier during periods when the stabilizer mechanism is disengaged at the master compass.

Transmission System

The Arma Mk VIII Mod 3A gyrocompass transmission system, like the Sperry transmission system, provides a means of transmitting the readings of the master compass transmitters to the remotely located repeater compasses in the ship. The 1-speed and 36-speed commutator transmitters (previously described with the master compass in the training course, *I. C. Electrician 2,* NavPers 10556) are driven by the azimuth followup motor that drives the spider in azimuth. The relay transmitters are similar to the commutator-type transmitter on the master compass and control the movement of the repeater compasses that indicate the readings of the master compass transmitters at the remote stations. The transmission system includes the repeater panel, relay transmitter repeater panel, relay transmitter, and repeater compasses.

REPEATER PANEL.—The repeater panel (fig. 7–13) is located adjacent to the control panel. It consists of 15

rotary switches. Nine of these are repeater switches that provide for selecting the supply from either the navigation or ordnance transmitters, from the 1-speed and 36-speed transmitters on the master compass, or from the navigation transmitter of the other master compass. The other three repeater switches provide for connecting the repeater to either the forward or after compass equipment. The remaining three switches control the dead reckoning equipment and the fire-control board.

The forward and after equipments are connected by port and starboard tie lines. The supply to the various sections of the compass equipment can be supplied from several different sources by means of transfer switches on the repeater panels.

Each compass repeater switch is provided with an overload indicator consisting of a transformer and neon lamp, similar to the overload relays used in the Sperry repeater circuits.

The fire control switches are not provided with an overload indicator because these are included on the fire-control switchboard. However, the fire-control switches (on the repeater panel) are provided with red and green target lights to indicate the energized circuits. The neon lamp is used only to indicate a blown-fuse condition.

RELAY TRANSMITTER REPEATER PANEL.—The relay transmitter repeater panel (fig. 7-13) is located directly below the repeater panel. This panel provides a means of connecting the relay transmitter (described later) to the master compass transmitters in place of one of the repeater compasses. This arrangement increases the number of repeater compasses that can be operated in the transmission system.

The relay transmitter repeater panel comprises four rotary switches, a fuse and switch panel, and a relay transmitter (located behind, and at the bottom of the repeater panel).

Three of these rotary switches are ON-OFF switches for

selecting the three commutator transmitters included in the relay transmitter units. The fourth rotary switch selects one of the three sources of supply for the course input to the 1-speed and 36-speed synchro receivers, also included in the relay transmitter unit.

The fuse and switch panel is located in the center of the relay transmitter repeater panel. It is provided with hinges for access to the three commutator transmitters in the relay transmitter unit located behind this panel.

RELAY TRANSMITTER.—The relay transmitter unit (fig. 7–18) consists of three commutator transmitters (navigation, target designation, and radar), a 1-speed followup

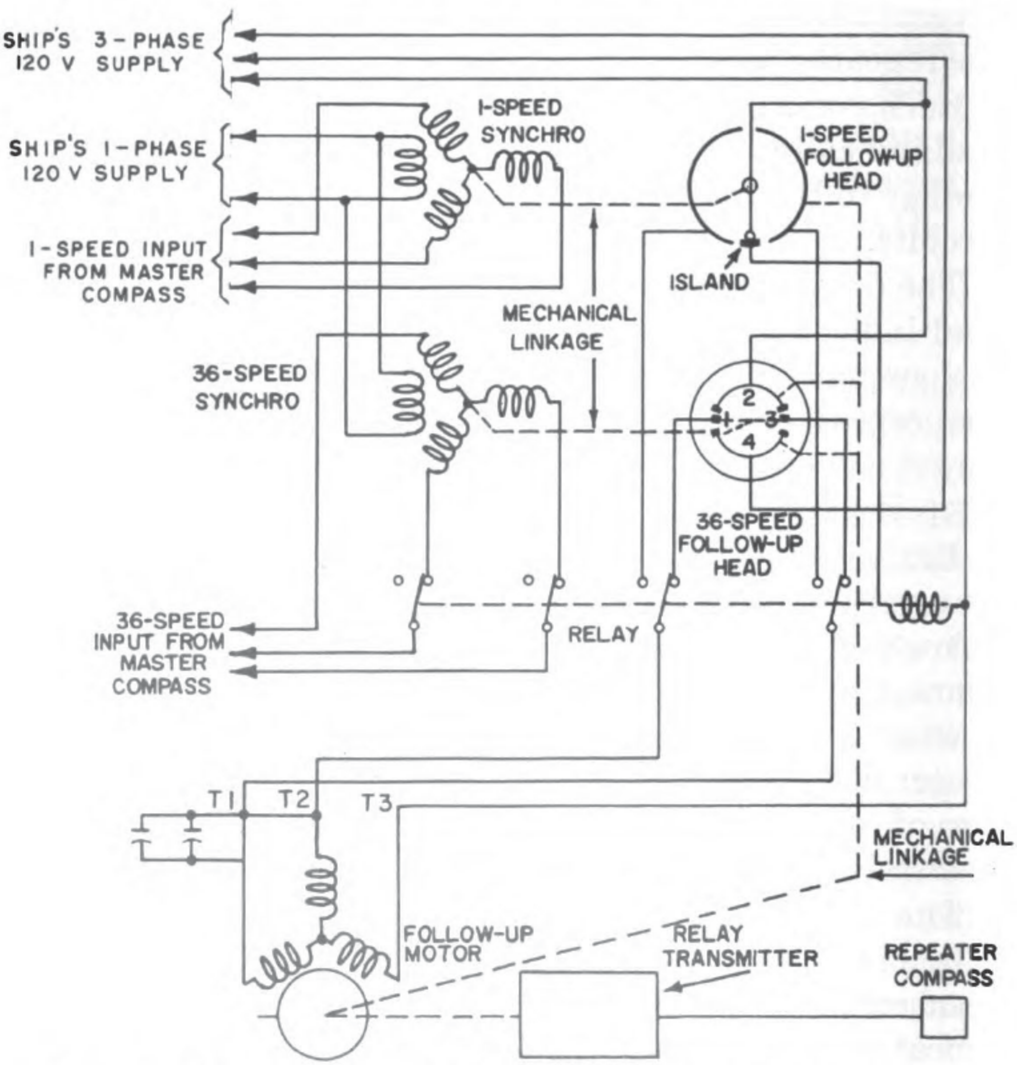


Figure 7—18.—Arma Mk VIII Mod 3A gyrocompass relay transmitter.

head mounted on a type-5N synchro receiver, a 36-speed followup head mounted on a type-5SN synchro receiver, and a followup motor.

The course input from the master compass transmitters is fed to the 1-speed and the 36-speed synchros, which control the operation of the followup motor that drives the three commutator transmitters in the relay unit through gearing. These transmitters are similar to, and completely interchangeable with, the commutator transmitters on the master compass. When the relay transmitter unit is first turned on, the 1-speed head synchronizes to within about $\pm 3°$ after which the 36-speed head takes control of the followup motor to bring the relay transmitter to the exact heading.

The 1-speed followup head comprises a roller-type contact assembly. The contact roller is mounted on the 1-speed synchro shaft and is connected to one phase of the ship's 3-phase power. This contact roller bears on a collector ring (mounted on the 1-speed followup head) that is divided into two large segments and one small segment. The large segments are connected to terminals $T1$ and $T2$, and the small segment is connected to terminal $T3$ of the followup motor. As the large segments are connected to the $T1$ and $T2$ terminals, a signal from the master compass causes the 1-speed synchro to turn the shaft and bring the contact roller to bear on the small segment. When the roller is on this segment, it operates the transmitter relay to energize the 36-speed synchro and transfers control of the followup motor from the 1-speed head to the 36-speed head.

The 36-speed followup head comprises a make-and-break contact assembly consisting of six contacts. Contacts ① and ③ are mounted on the 36-speed synchro shaft and connected to the $T2$ and $T1$ terminals respectively of the followup motor. These contacts determine the direction of rotation of the followup motor. The remaining four contacts are mounted on the 36-speed followup head and

connected in pairs to comprise head contacts ② and ④. These two sets of head contacts are connected across one phase of the ship's 3-phase power supply.

In the synchronized position (fig. 7–18), shaft contacts ① and ③ are closer to head contacts ② than to head contacts ④. Normally, a signal fed to the 36-speed synchro causes shaft contacts ① and ③ (depending on the direction of rotation) to close head contacts ② instead of head contacts ④. This action applies single-phase power to terminals *T*2 and *T*3, and energizes terminal *T*1 through a capacitor, causing the 3-phase followup motor to operate as a split-phase motor.

The followup motor drives the 36-speed followup head in the same direction as that of the 36-speed synchro shaft. When the synchronizing position is reached, the input signal is nulled and the synchro shaft stops to open the contacts and deenergize the followup motor. This low-torque operation of the followup motor is the normal function of the relay transmitter unit.

However, if the followup motor is unable to drive the followup head fast enough to keep up with the input signal, shaft contact ① (for clockwise rotation) pushes back head contacts ② until shaft contact ③ closes head contacts ④. This action applies 3-phase power to terminals *T*1, *T*2, and *T*3 of the followup motor to obtain maximum motor torque to drive the followup head. If the input signal is in the reverse direction, the followup head reverses the connections to terminals *T*1 and *T*2 and causes the followup motor to run in the opposite direction.

A magnetic damper on the shaft of the 36-speed synchro smoothes out any fluctuations in the synchro signal. A detent is provided also between the synchro shaft and the shaft contacts to allow the shaft to complete its travel with only a moderate amount of thrust between the contacts. The two synchros in the relay transmitter unit are provided with overload lights that also serve as blown-fuse indicators. A flywheel damper on the followup motor

prevents hunting and smoothes out oscillations of the followup system.

TRANSFER SWITCHING.—Tie lines are provided between the forward and after gyrocompass equipments so that the repeater compasses can be supplied from several different sources.

The outputs of the forward master compass ordnance and navigation transmitters are fed to the supply switch on the forward relay transmitter repeater panel and to the repeater switches on the forward repeater panel. Also, the output of the navigation transmitter is fed to a tie line switch (on the repeater panel) that is connected to port and starboard cables, either of which can be used to supply this output to the after gyrocompass equipment. The tie-line switch on the receiving end of the line (on the after repeater panel) is provided with red and green indicator lights to denote the energized cable.

Therefore, each relay transmitter unit is provided with input-signal sources from the (1) ordnance and (2) navigation transmitters of its own master compass, and (3) navigation transmitter of the other master compass. These three sources of supply are fed also to the switches that control the most important navigation repeaters.

Each of the transmitters (target designation, navigation, and radar) in the relay transmitter unit are provided with an ON-OFF switch. The outputs of the target designation and navigation transmitters are fed to their own instruments and also to a tie-line switch through port or starboard cables to similar instruments in the other gyrocompass equipment. Hence, two sources of supply are available to all the repeaters and course-indicating instruments controlled from the repeater panels.

The outputs of the radar transmitters in the relay transmitter unit are fed directly to a selector switch located at the radar equipment to select between the forward and after supplies.

QUIZ

1. Name the four systems that comprise the complete gyrocompass system in addition to the master compass.
2. Name the five principal components that comprise the Sperry Mk XI Mod 6 gyrocompass control system.
3. Name the primary and emergency power supply sources for the Sperry Mk XI Mod 6 gyrocompass system.
4. What five units comprise the motor-generator of the Sperry Mk XI Mod 6 gyrocompass drive system?
5. (a) What is the type of power supplied by the a-c generator to the gyro rotor, to the amplifier, and to the followup system in the Sperry Mk XI Mod 6 gyrocompass system? (b) What units are supplied by the d-c generator?
6. What is the purpose of the speed regulator in the Sperry Mk XI Mod 6 gyrocompass control system?
7. How is the initial adjustment of the pressure on the carbon piles accomplished in the Sperry speed regulator?
8. How is the operating speed of the motor-generator regulated in the Sperry speed regulator?
9. What three actions occur when ship's 3-phase supply voltage or frequency drops below ± 10 percent of the normal value and the speed regulator operates to deenergize the battery throwover relay?
10. Name the four conditions that are indicated by the alarm system of the Sperry Mk XI Mod 6 gyrocompass system.
11. What is the primary power source for the entire alarm circuit in the Sperry Mk XI Mod 6 gyrocompass system.
12. What is the primary function of the Sperry gyrocompass followup system?
13. What is the source of the input signal to the followup amplifier in the Sperry followup system?
14. For what purpose is the output of the Sperry followup amplifier used?
15. (a) What is the relation between the induced voltages in the secondary coils on the outside legs of the Sperry followup transformer (fig. 7–5)? (b) Why?

IN THE SPERRY MK XI MOD 6 GYROCOMPASS FOLLOWUP SYSTEM, FIGURE 7–5, FOR QUESTIONS 16 THROUGH 24:

16. What is the relation between the (a) magnitude of the output voltage of the followup transformer and the coil (2) and coil (3) voltages and (b) the phase of the output voltage and the coil voltages?

17. (a) How many channels are provided? (b) Why? (c) How are the voltage amplifier channels connected (push pull or parallel)?

18. (a) How are the thyratrons in each channel connected (push pull or parallel)? (b) Why?

19. What is the relative polarity of the plate voltages of the lower channel with respect to those of the upper channel (the same or opposite)?

20. If the input signal causes the grid of *V1A* to go more negative and the grid of *V1B* to go more positive during the half cycle that the plates of *V1* are positive (solid polarity markings): (a) What will be the effect on the plate current of *V1A* (increase or decrease)? (b) What will be the effect on the plate current of *V1B*? (c) What will be the relative polarity of the signal applied to the grids of *GR1* and *GR2* (negative going or positive going)? (d) Which of the thyratrons will conduct? (e) Why are *V2A* and *V2B* nonconducting during this half cycle?

21. During the second half cycle (dotted polarity markings): (a) Why is the twin triode *V1A* and *V1B* nonconducting? (b) Why are thyratrons *GR1*-*GR2* nonconducting? (c) What is the relative polarity of the output signal of *V2* across *R2* (positive going or negative going)? (d) What is the effect of this signal on *GR3* and *GR4*?

22. (a) In the absence of a signal voltage at *T2*, the a-c bias from *T1* has what effect on the thyratrons? (b) What effect does this action have on the followup motor torque?

23. What is the purpose of the rate circuit provided in each amplifier channel of the Sperry followup system?

24. What would be the effect on the operation of the system if one of each pair of power tubes and one of the amplifier tubes should fail?

25. What is the purpose of the transmission system in the Sperry gyrocompass system?

26. In addition to driving the phantom element in azimuth, what two components on the master compass does the azimuth motor drive?

27. What is the purpose of the overload relays in the 1-speed and the 36-speed transmitter circuits of the Sperry transmission system?

28. How are the repeater panel and the relay transmitter repeater panel arranged with regard to the switching facility of the repeater compasses in the Sperry transmission system?

29. What is the function of the relay transmitter?

30. Name the five components that comprise the Sperry relay transmitter.

31. In the relay transmitter (fig. 7–8, B): (a) What is the function of the followup system (followup motor, synchro units, and amplifier)? (b) What is the signal source for the primaries of the synchro control transformers? (c) What is the source for the amplifier? (d) What does the output of the amplifier energize? (e) What two devices does the followup motor drive? (f) What does the output of the commutator transmitter energize? (g) What type of stator winding is used in the commutator transmitter? (h) How do the three voltages selected by each set of brushes in the relay transmitter compare with the stator voltages of a conventional-type synchro transmitter? (i) What is the function of the reactor connected in shunt with the 60-cycle input to the commutator transmitter?

REFERRING TO FIGURE 7–9 FOR QUESTIONS 32 THROUGH 37:

32. (a) What two types of amplifiers comprise the relay transmitter amplifier? (b) What is the function of *P*3?

33. With no signal on *T*1: (a) What is the relation between the plate current of *V*1*A* and that of *V*1*B*? (b) What are the relative magnitudes of the currents in the two halves of *L*1? (c) What is the relative magnitude of the signal voltage across *L*1? (d) What are the relative magnitudes of the currents flowing in the two opposing field windings of the followup motor? (e) What is the relative magnitude of the followup motor torque?

34. If a signal is applied to *T*1 that drives one grid of *V*1 in a positive direction and the other grid in a negative direction, why can the next half cycle, when the grid signal reverses its polarities, be disregarded?

35. If the input signal to *T*1 drives the grid of *V*1*A* in a negative direction and the grid of *V*1*B* in a positive direction during the half cycle that the plates of *V*1 are positive: (a) What will be the relative magnitudes of the plate currents of *V*1*A* and *V*1*B*? (b) What will be the polarities of the signal voltage developed

across *L*1? (c) What will be the relative polarities of the signal developed on the grids of *GR*1 and *GR*2? (d) What will be the relative magnitude of the average plate currents of *GR*1 and *GR*2? (e) Why?

36. What is the purpose of the rate capacitors, *C*1, *C*2, *C*7, and *C*8?

37. (a) Normally, the controlling signal voltage for the relay transmitter is obtained from which control transformer (the 1-speed or the 36-speed CT)? (b) What is the action of the copper oxide rectifiers across the 36-speed *CT* when the relay transmitter is more than 5° from the synchronous position and why? (c) What is the action of the copper oxide rectifiers when the relay transmitter is less than 5° from the synchronous position? (d) What is the function of the 6.3-volt winding of *T*2?

38. (a) What is the purpose of the differential alarm relay in the Sperry gyrocompass transmission system? (b) What is the range in degrees that the transmitter is allowed to diverge before the alarm is sounded? (c) What are the primary sources of the two inputs to the differential receiver stator and rotor of the alarm relay? (d) How is the differential alarm relay set to allow for a predetermined divergence between the relay transmitter and master-compass transmitter before the alarm is sounded?

39. Name the three principal components that comprise the Arma Mk VIII Mod 3A gyrocompass control system.

40. What is the type of power supplied by the a-c generator to the gyro rotors in the Arma Mk VIII Mod 3A gyrocompass control system?

41. What are the two functions of the speed control mechanism in the Arma Mk VIII Mod 3A gyrocompass control system?

REFERRING TO FIGURE 7–11 FOR QUESTIONS: 42 THROUGH 45:

42. How is manual adjustment of the gyro rotor speed made to obtain the correct speed?

43. When the gyro speed is correct: (a) What action occurs between *L*2 and *C*1? (b) What effect do *L*2 and *C*1 have on winding *B* of the reversible motor normally? (c) What relative torque is developed by the reversible motor normally?

44. If the ship's supply voltage and frequency drop below normal: (a) What is the initial effect on the speed of the m-g set? (b) What is the initial effect on the frequency of the gyrocompass supply voltage fed to *C*1–*L*2? (c) What kind of impedance (*L* or *C*) effectively shunts winding *B* of the reversible motor? (d) What action occurs in the reversible motor? (e) Is the

rheostat arm driven in a direction to increase or decrease the rotor circuit resistance of the 3-phase motor? (f) What is the effect of the action of the reversible motor on the gyrocompass supply voltage and frequency?

45. What is the purpose of capacitor $C3$?

46. Why does the gyro voltage indicator show a reduced value at high latitudes?

47. On the Arma Mk VIII Mod 3A gyrocompass control panel: (a) For what purpose is the panel used? (b) Under what conditions is the damping cutout lamp energized? (c) How is the alarm selector switch operated to locate trouble? (d) Where are the fuses for the protection of the various circuits located? (e) What is the function of a thermostatic time delay relay that is operated in connection with the motor-generator switch? (f) What is the purpose of the "a-c only" positions on the a-c and d-c supply switch? (g) For what type of requirement is the gimbal stabilizer amplifier switch turned on? (h) Where are the speed control mechanism and the motor-generator rheostat located? (i) Why is the resistance cutout of the motor rotor circuit when the gyros are started?

48. What is the primary function of the Arma Mk VIII Mod 3A gyrocompass azimuth followup system?

49. What are the three principal components comprising the followup panel (fig. 7–13)?

50. Name the three principal components that comprise the automatic damping eliminator circuit in the Arma gyrocompass followup system.

51. What action occurs in the Arma followup system when the ship turns at a rate in excess of 40° per minute and the amount of turn exceeds 15°?

52. What is the function of the speed acceleration damping cutout unit in the Arma followup system?

53. Name the two principal components of the Arma speed acceleration damping cutout unit.

54. What circuits are energized by the followup magnet transformer and the damping cutout transformer mounted on the back of the Arma control panel?

55. What is the function of the relay in the primary of the interstage transformer between the voltage and power amplifier stages of the Arma followup system?

REFERRING TO FIGURE 7–15 FOR QUESTIONS 56 THROUGH 61:

56. With no signal developed across *T*1 or *T*2, what is the purpose in having a limited amount of conduction in *GR*1 and *GR*2?

57. If for example, a signal is induced in the secondaries of *T*2 so that the grids of *GR*1 and *GR*2 are both positive when the plate of *GR*1 is positive: (a) What action occurs in *GR*1? (b) What action occurs in *GR*2 and why?

58. On the negative half cycle of the input signal assumed in the preceding question: (a) What action occurs in *GR*1 and why? (b) What action occurs in *GR*2 and why?

59. With the applied signal as indicated in the preceding question, (a) What action occurs in the followup motor armature? (b) As the followup motor drives the azimuth ring into alinement with the sensitive element, what is the effect on the input signal to the amplifier? (c) What stops the motor?

60. How is tube 1 failure in the power amplifier stage indicated?

61. (a) What are the functions of the *R*11 and *C*22? (b) What is the phase relation between the antihunt voltages on the grids of *GR*1 and *GR*2?

62. What is the function of the alarm system used with the Arma Mk VIII Mod 3A gyrocompass?

63. What is the purpose of the stabilization cutout relay in the Arma Mk VIII Mod 3A followup system?

64. Name the principal components of the Arma Mk VIII Mod 3A relay transmitter.

65. From what source is the input to the 1-speed and 36-speed synchros of the Arma Mk VIII Mod 3A relay transmitter derived?

66. What is the function of the 1-speed and 36-speed followup heads mounted on the 1-speed and 36-speed synchros of the Arma Mk VIII Mod 3A relay transmitter?

67. (a) In figure 7–17, how is low-torque operation of the 3-phase followup motor accomplished for normal operation of the Arma Mk VIII Mod 3A relay transmitter? (b) How is maximum torque obtained from the 3-phase, followup motor of the Arma Mk VIII Mod 3A relay transmitter when the followup motor is unable to drive the followup head fast enough to keep up with the input signal?

68. Name the three input signal sources to each relay transmitter.

CHAPTER 8

DEAD RECKONING SYSTEM

The dead reckoning system, circuit *TL*, provides a means of indicating the ship's position in latitude and longitude on an appropriate chart by means of a range-bearing projector (plotting light), or on mechanical dials. It may also record graphically on an appropriate chart, the ship's travel relative to a fixed starting point. When properly set at the starting point, the mechanisms of the dead reckoning equipment indicate continuously the ship's latitude and longitude by computing mechanically the distance traveled by the ship and the ship's course. The distance traveled is computed from the input received from the underwater log; the course input is received from the master compass.

Dead Reckoning Analyzer

A dead reckoning system comprises a (1) dead reckoning analyzer; (2) dead reckoning indicator; and (3) dead

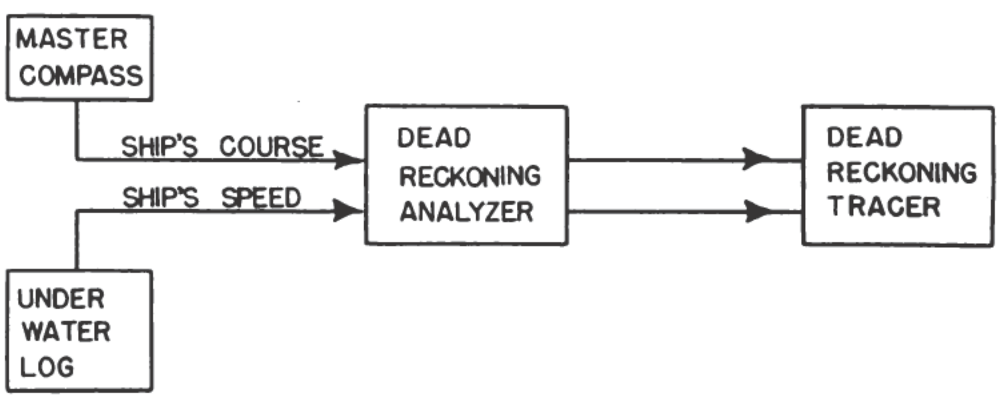


Figure 8—1.—Dead reckoning system block diagram.

reckoning tracer. The dead reckoning indicator is usually included with the tracking mechanism in the dead reckoning tracer. A block diagram of the dead reckoning system is illustrated in figure 8–1.

DEAD RECKONING EQUIPMENT

The dead reckoning analyzer (DRA) receives the ship's distance input from the underwater log system, and the ship's course input from the master-compass 1-speed transmitter. These two inputs are combined to determine and indicate the total distance and also the overall

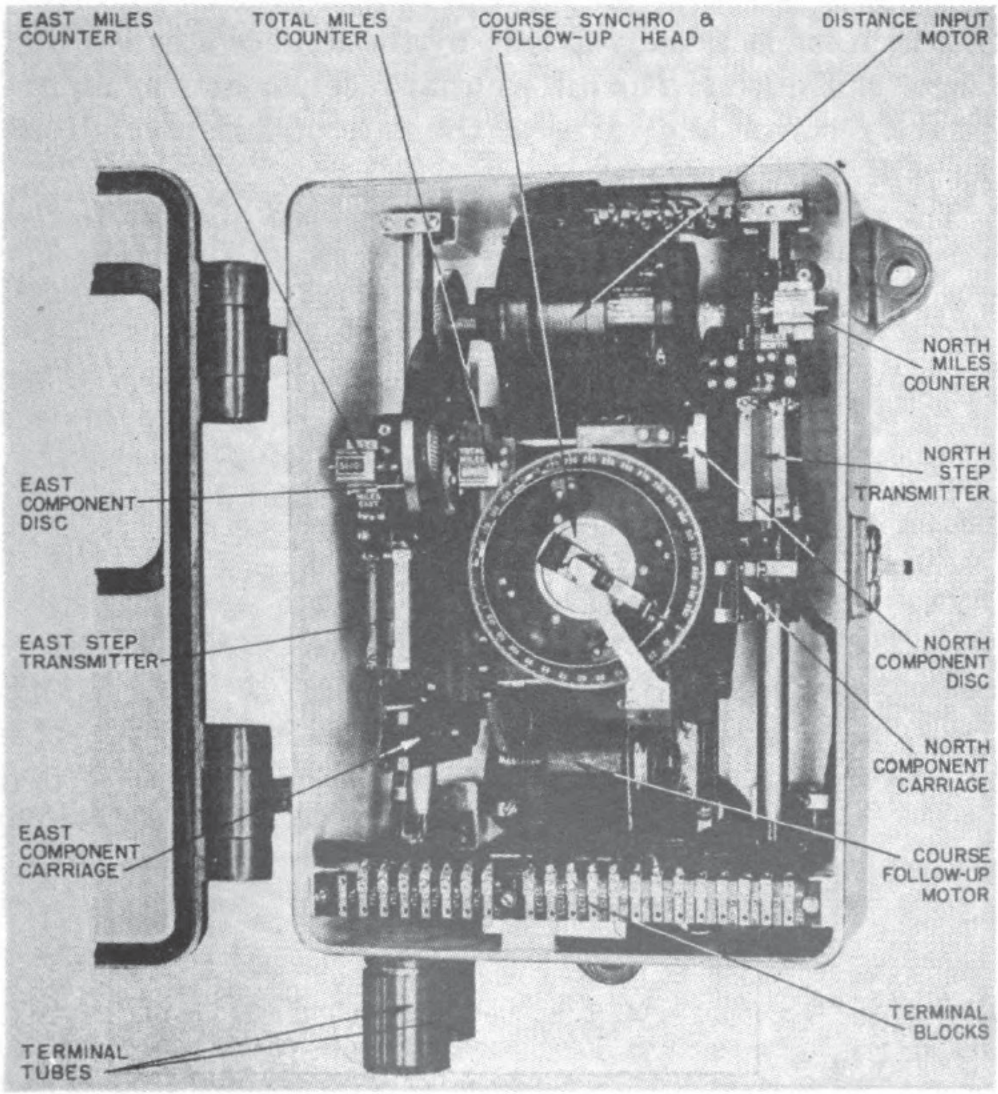


Figure 8—2.—Dead reckoning analyzer.

distances in a north-south and an east-west direction traveled by the ship from any given starting point. This unit consists of (1) a distance converter; (2) roller carriages; and (3) a ship's course crank arm mechanism enclosed in a metal case provided with a hinged cover (fig. 8–2). The east miles counter, north miles counter, total miles counter, and course dial are visible through a window in this cover. The dead reckoning analyzer is designed for bulkhead mounting and is located in the chart house.

DISTANCE CONVERTER—The distance converter is illustrated in the schematic diagram of the DRA in figure 8-3. It includes a distance input differential synchro receiver, G, which is electrically driven by the underwater log distance transmitter. The differential receiver acts as an ordinary receiver and turns at the rate of 360 revolutions per mile.

The distance input synchro, *G*, is geared directly to the

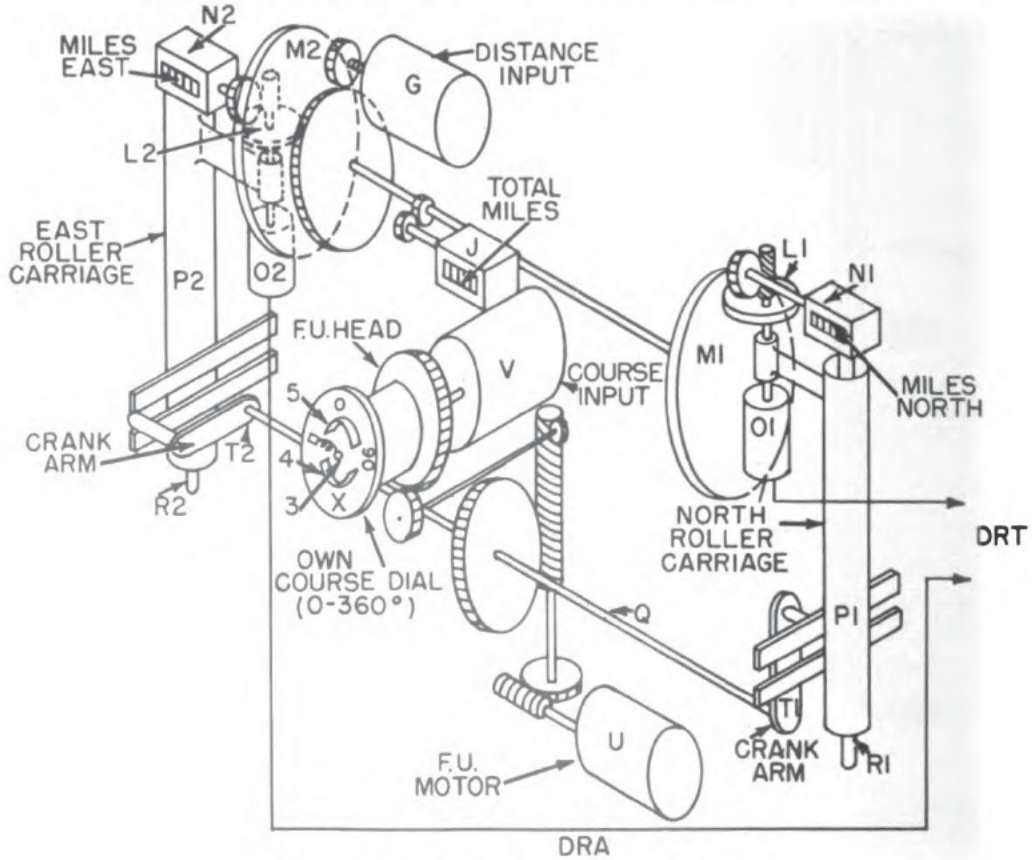


Figure 8—3.—DRA schematic diagram.

shaft on which the two disks, $M1$ and $M2$, are mounted; therefore, their rotation is directly proportional to the distance traveled. It is from the rotation of these disks that the north and east components of the ship's travel are taken. Thus, they are called the north and east component disks. The counter, J, which is geared to the shaft that drives the disks, indicates the total miles traveled by the ship.

Roller carriages.—The roller carriages, $P1$ and $P2$ (fig. 8–3), are mounted on guide rods $R1$ and $R2$. The ends of the roller carriages are provided with a set of guide rollers (not shown) to ensure free motion of the carriages along the guide rods. The carriages are positioned along the guide rods by a crank arm mechanism that is controlled by the signal from the master compass. The speed rollers, $L1$ and $L2$, are mounted on the north and east roller carriages respectively, and bear against the corresponding disks, $M1$ and $M2$. These rollers are positioned so that their speeds are proportional to the north-south and east-west components respectively of the ship's speed.

When a carriage is positioned so that its speed roller is near the edge of its component disk, the roller is driven a maximum number of revolutions by each revolution of the disk. As the speed roller is moved toward the center of the disk, it is driven at a slower rate. When the roller is at the center of the disk, it is stationary, and no motion is transmitted to its shaft. Conversely, if the speed roller passes the center of the disk, it will be driven in the opposite direction.

The crank arm mechanism positions the carriages so that on a north-south or an east-west course, one of the speed rollers is at the edge of, and the other speed roller is at the center of, its component disk. Thus, on a north or south course, the north speed roller is driven at a maximum rate, and the east speed roller is stationary. Conversely, on an east or west course, the east speed roller

is driven at a maximum rate, and the north speed roller is stationary. On an intermediate course, both speed rollers are driven, the respective rates of rotation being proportional to the north-south and the east-west components of the ship's course.

The speed rollers, $L1$ and $L2$, drive the north counter, $N1$, and the east counter, $N2$, through worm gears to indicate the ship's travel in total miles north and in total miles east. Motions to the north or to the east are assumed as positive and cause the counters to indicate increasing readings. Conversely, motions to the south or to the west are assumed as negative and cause the counters to indicate decreasing readings.

The d-c step-by-step transmitters, 01 and 02, are mounted on the shafts of the speed rollers, $L1$ and $L2$, respectively. These transmitters control the step-by-step receivers, $V1$ and $V2$, respectively, in the dead reckoning indicator and also the receivers, $X1$ and $X2$, in the dead reckoning tracer. The rotation of these receivers is therefore directly proportional to the north or east components of the ship's travel and can be used to operate the desired indicating and recording mechanisms in the dead reckoning tracer.

SHIP'S COURSE CRANK ARM MECHANISM.—The ship's course crank arm mechanism (fig. 8-3) includes a course input synchro receiver, V, that is electrically driven by the master-compass transmitter. This receiver cannot furnish sufficient power to operate the crank arm mechanism; hence, a followup system is required. The synchro receiver controls the followup motor, U. The motor, through a gear train, moves a compass dial, X, and the crank arms, $T1$ and $T2$, that control the positions of the north and east roller carriages, $P1$ and $P2$, respectively.

The crank arms are mounted at right angles to each other on a common shaft (fig. 8-3). The crank pins engage slots in the roller carriages. These slots are at right angles to the guide rods, $R1$ and $R2$. When either

crank arm is at right angles to its associated guide rod, the throw of the crank arms positions its speed roller at the center of the associated disk, and no motion is transmitted to it. Conversely, when either crank arm is parallel to its guide rod, the throw of the crank arms positions its speed roller at the edge of the associated disk, and maximum motion is transmitted to it.

The ship's course dial, *X*, the split ring segments, 4 and 5, and the crank shaft, *Q*, are geared to the followup motor, *U*, and rotate with it when the motor is energized. The rotor of the course synchro receiver will not change its position with respect to its stator except when the course indication from the master compass changes.

Contact brush 3 is mounted on the shaft of the course synchro receiver, which extends through the ship's course dial mounting and can rotate freely within it. This brush can come into contact with either of the two segments of the split ring, which are connected to the followup motor. This action will cause the followup motor to run either in a clockwise or in a counterclockwise direction, depending on which segment is contacted by the brush. Normally, the brush is in the dead space between the rings and does not touch either ring, and the followup motor does not operate.

When the rotor moves in response to a change in course, contact is made on one of the split-ring segments. The followup motor then moves the crank arms, the ship's course dial, and the split ring assembly in a direction that brings the split ring into synchronism with the brush. In this position the course dial indicates the true heading, and the roller carriages are correctly positioned by the crank arms to provide the proper north and east components as the output of the analyzer. When there is no longer a change in compass course, the synchro receiver rotor stops turning but the segments continue to turn until the brush is in the dead space between the segments and the followup motor stops.

Dead Reckoning Indicator

The dead reckoning indicator (DRI) is contained in the tracking mechanism of the dead reckoning tracer. It consists of a dial unit assembly that includes the latitude motor and dials, longitude motor and dials, and latitude correction mechanism (fig. 8–4). The latitude and longitude dial assemblies each consist of two concentric dials. The outer latitude and longitude dials are graduated in degrees and the inner latitude and longitude dials are graduated in minutes.

A schematic diagram of the DRI is illustrated in the schematic for the DRT in figure 8–6. The output from

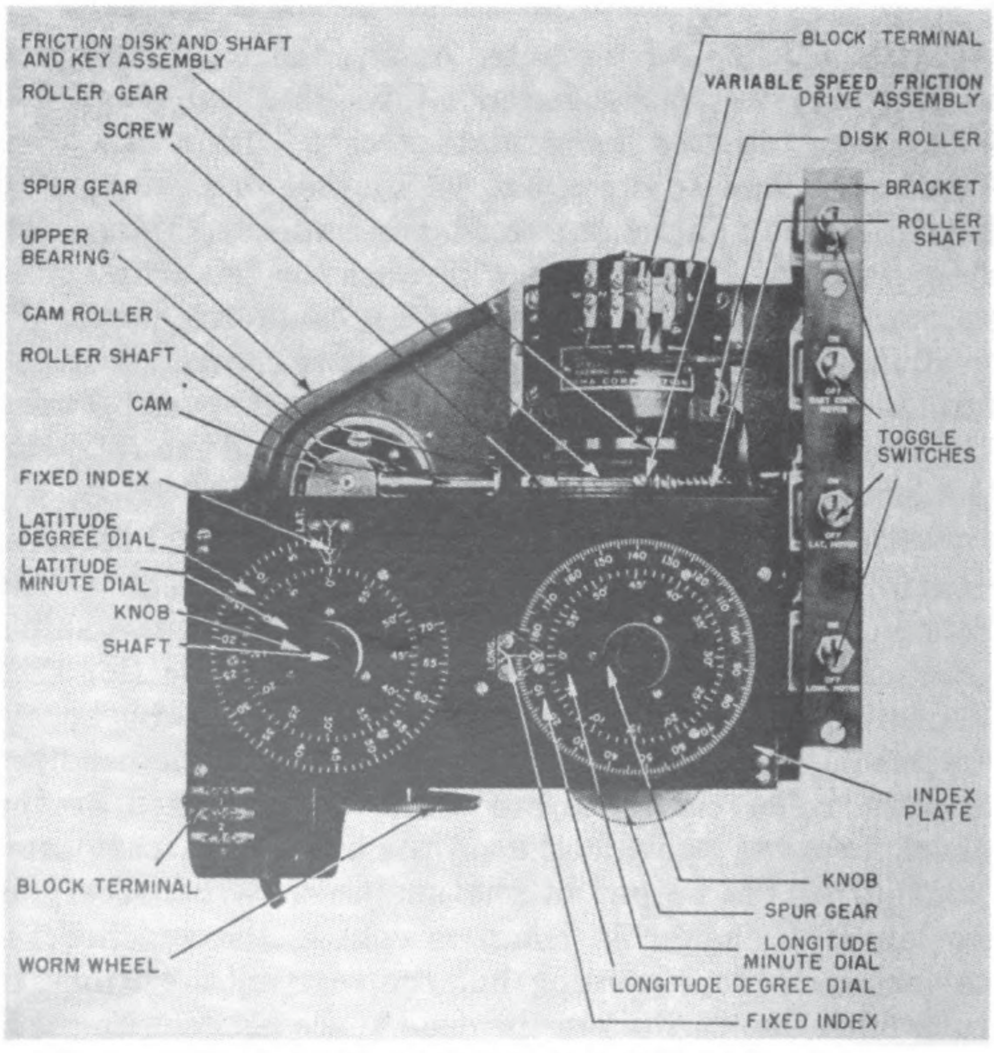


Figure 8—4.—Dead reckoning indicator.

the north step transmitter, 01, in the DRA drives the latitude step receiver, $V1$, that is geared to the latitude dials. Similarly, the output of the east step transmitter, 02, drives the longitude step receiver, $V2$, that is geared indirectly to the longitude dials through a speed correction mechanism.

The latitude dials, $F1$, are geared directly to the latitude step receiver. There is a fixed relation between a degree of latitude and a degree of displacement of the receiver rotor. (One degree of latitude is approximately equal to 60 nautical miles anywhere on the earth's surface.) A reversing latitude and longitude indicator switch, T, is provided for reversing the direction of rotation of the latitude dials when the equator is crossed.

LATITUDE CORRECTION MECHANISM.—The longitude dials cannot be geared directly to the longitude step receiver because the relation between a degree of longitude and a degree of displacement of the longitude step receiver, $V2$, varies with the latitude. The latitude correction mechanism (fig. 8–6) is introduced between the longitude receiver, $V2$, and the longitude dials, $F2$, in order to adjust the number of miles east-west per degree of longitude in accordance with the latitude of the ship. This mechanism consists of a friction disk and roller assembly. The disk is attached to the shaft of the longitude motor, $V2$, and drives the friction roller at a speed proportional to the radial distance to the center of the disk. A cam follower is driven by a cam geared to the latitude degree dial and controls the position of the friction roller to provide the proper speed ratio for the given latitude. Thus, at 60° latitude, where 1° of longitude equals approximately 30 miles, the cam holds the friction roller in a position so that it turns twice as fast as it would turn at the equator. A spur gear meshes with a gear on the friction roller that drives the longitude dials, $F2$. The reversing switch, T, also provides for changing the direction of rotation of the longitude dials when the 0° or 180° meridian of longitude is crossed.

Dead Reckoning Tracer

The dead reckoning tracer (DRT) consists of (1) a tracking mechanism; (2) a chart board that includes the pencil carrier assembly; and (3) an auxiliary plotting board (fig. 8–5). The auxiliary plotting board is included with the DRT for plotting ranges and bearings of contacts that are being tracked, and for plotting own ship's course. The DRT is housed in a metal case designed for horizontal mounting on a table or cabinet and is located in the combat information center.

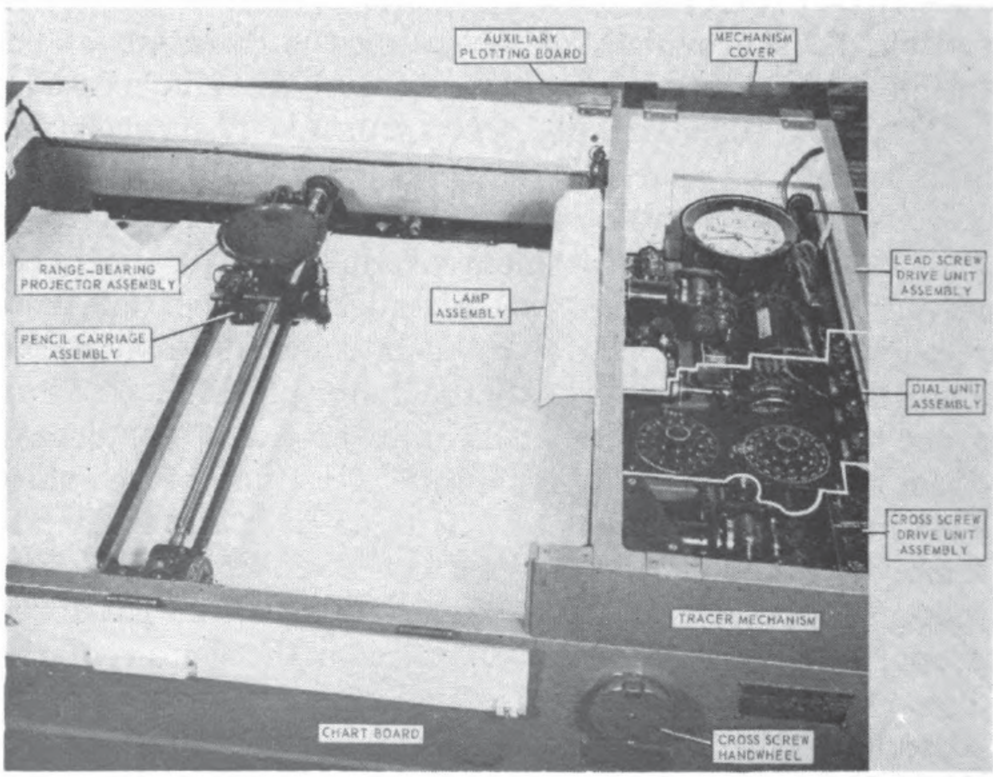


Figure 8—5.—Dead reckoning tracer with auxiliary plotting board.

A schematic diagram of the DRT is illustrated in figure 8–6. The DRT, in addition to the DRI, receives from the DRA the outputs of the north and the east step transmitters., 01 and 02, that actuate the step receivers, *X*1 and *X*2, respectively. These step receivers in turn operate the mechanisms that drive the pencil carrier to

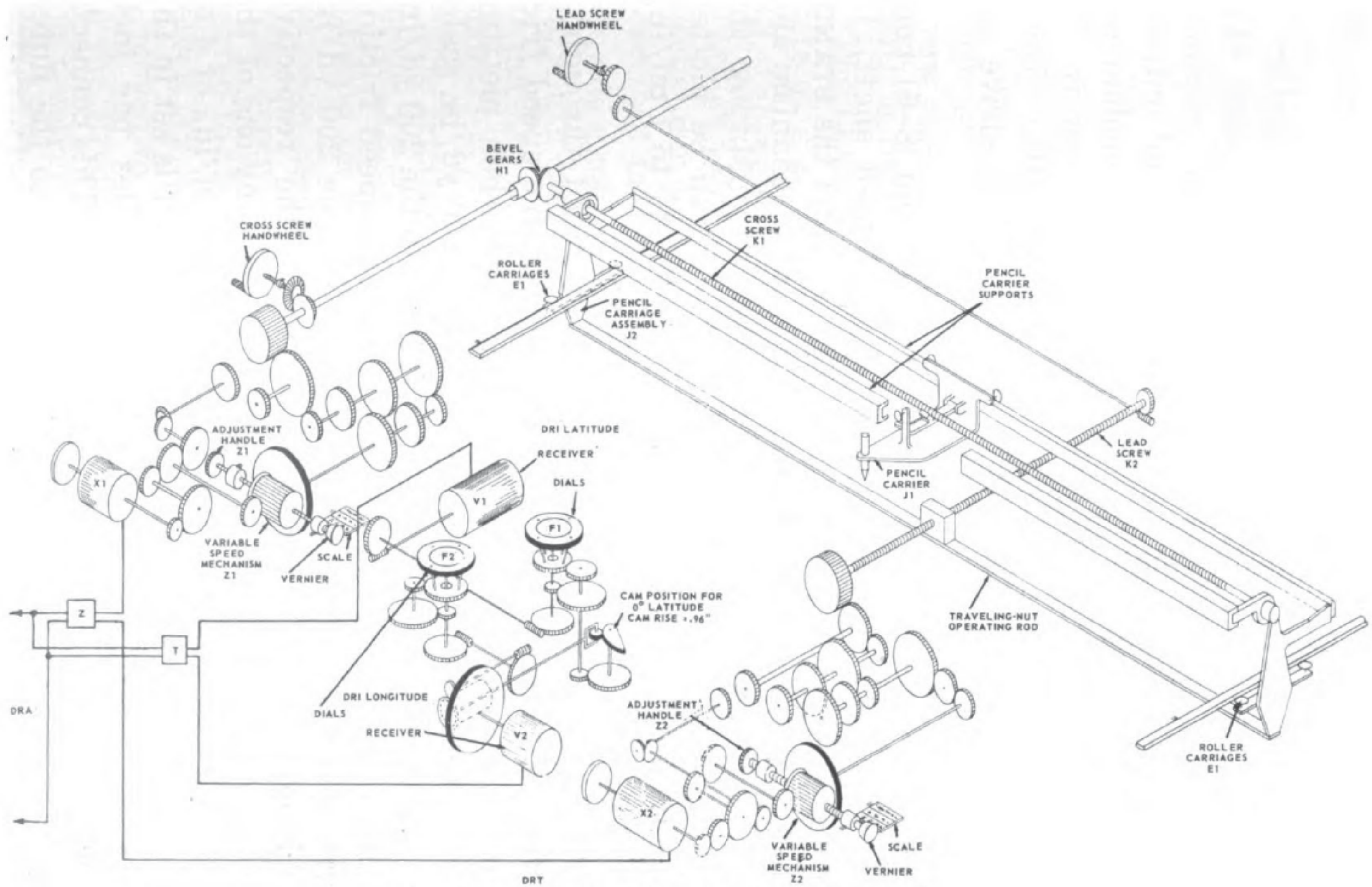


Figure 8—6.—DRT schematic diagram.

record a graphical plot of the distance and direction traveled by the ship. The receivers, $X1$ and $X2$, are turned at the same rate as the speed rollers, $L1$ and $L2$, are turned by the component disks, $M1$ and $M2$.

TRACKING MECHANISM.—The tracking mechanism is located in the right-hand section of the DRT case (fig. 8–5). It consists of a cross screw drive unit assembly and a lead screw drive unit assembly. The dial unit assembly of the DRI is also included in this mechanism. The north DRA transmitter actuates a receiver in the cross screw drive assembly, and the east DRA transmitter actuates a receiver in the lead screw drive assembly.

The CROSS SCREW DRIVE UNIT ASSEMBLY (fig. 8–6) consists of a receiver, $X1$, geared to the fluted shaft, Y, through a variable speed mechanism, $Z1$, and the STANDARD-200 yd/in. shaft. The variable speed mechanism and gear shift assembly provide a means of changing the latitude scale to which the ship's course can be plotted from the STANDARD-200 yd/in. scale to the ¼ to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/ in. scales.

The 200 yd/in. tracking scale is provided through a system of gearing that bypasses the variable speed friction drive assemblies that are employed when plotting to any of the other scales. To select the 200 yd/in. scale, the STANDARD-200 yd/in. gear shift is set in the 200 yd/in. position. In this position the variable speed friction drive assemblies rotate but do not affect the 200 yd/in. tracking because no load is placed on the respective cluster gear bracket assemblies. To select any one of the three tracking scales, 1/4 to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/in., the STANDARD-200 yd/in. gear shift is set in the STANDARD position, and the 3-position miles per inch gear shift is set to the desired range scale. This connects the variable speed friction drive assembly to the fluted shaft, Y, through the selected gear ratio. A final adjustment allows any scale within the selected range to be used

by a fine adjustment handle on the variable speed assembly. The handle moves the adjustable drive roller (connected to the rotor of receiver $X1$ through gears) along its axis of rotation to vary the distance of the drive roller from the center of the friction disk. A scale graduated in miles per inch is provided with a vernier dial graduated in hundredths of a mile per inch for fine adjustments.

The friction disk that is driven by the cross screw receiver, $X1$, drives the fluted shaft, Y, through gears. The rotation of this shaft is transmitted to the cross screw, $K1$, by two bevel gears $H1$ on the pencil carriage assembly, $J2$. This action moves the clasp nut attached to the pencil carrier, $J1$. The bevel gears and the cross screw are free to move along the fluted shaft while the shaft is rotating.

The LEAD SCREW DRIVE UNIT ASSEMBLY (fig. 8–6) consists of a receiver, $X2$, that is geared to the lead screw, $K2$, through a variable speed mechanism, $Z2$, and the STANDARD-200 yd/in. gear shift. This variable speed mechanism and gear shift assembly are similar to those described in the cross screw drive unit assembly. They provide a means of changing the longitude scale to which the ship's course can be plotted from the 200 yd/in. scale to the 1/4 to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/in. scales.

The friction disk that is driven by the lead screw receiver, $X2$, drives the lead screw, $K2$, through gears. The rotation of the lead screw, $K2$, moves the entire pencil carriage assembly, $J2$, along the tracking board. The cross screw, $K1$, is supported by an assembly that is geared to the lead screw, $K2$, by a clasp nut. As the receiver, $X2$, turns the lead screw, $K2$, the cross screw, $K1$, is moved to the right or left across the table, depending on the direction of rotation of $X2$. At the same time as the receiver, $X1$, turns the cross screw, $K1$, the pencil carrier, $J1$, is moved up or down, depending on the direction of rotation of $X1$.

Thus, as the lead screw and the cross screw are driven by their receivers in response to the impulses received from the DRA, the north and east components of the ship's motion are transmitted to the pencil. This action causes the pencil to move horizontally and vertically across the tracking board to trace a line that is the resultant of these components of the ship's travel. On a north or south course, only the cross screw is turned to trace a vertical line. On an east or west course, only the lead screw is turned to trace a horizontal line. On any other course, both the cross screw and the lead screw are turned to trace a line that bears the same relation to a vertical line as the ship's course bears to the meridian. The line represents, to scale, the actual course traveled by the ship.

A component tracking (interchange) switch, *Z*, is provided so that the north and east component inputs from the DRA can be interchanged to shift the plotting axes. This arrangement permits using the longer dimension of the tracking table as either north or east, depending on whether the ship's course is predominantly north-south or east-west. However, it is usually preferable to operate the DRT with the north component, actuating the cross screw, *K*1 (long dimension, east), as illustrated by the gear diagram in figure 8–6. Roller carriages *E*1 are provided to keep the pencil carriage assembly, *J*2, alined with the table.

The clasp nuts that drive the cross screw, *K*1, and the lead screw, *K*2, to transfer motion to the pencil carriage, *J*1, and the pencil carriage, *J*2, can be released. This arrangement permits moving the pencil independently of the screws to any desired position on the table. When they reach the end of the screws the clasp nuts disengage automatically, to prevent damage to the instrument.

CHART BOARD.—The chart board consists of a recessed plotting surface in the left-hand section of the DRT case below the pencil carrier assembly (fig. 8–5). The pencil

automatically traces the movements of the ship on a chart inserted on the plotting surface.

The pencil carrier assembly, *J*1, is illustrated in figure 8–7. The pencil carrier assembly is supported by the pencil carriage assembly and includes the pencil, the pencil magnet, and the range-bearing projector. The pencil magnet is actuated by means of a clock-driven switch that energizes the pencil-magnet circuit at predetermined intervals. This action causes the magnet to lift the pencil from the chart periodically to omit the trace to facilitate interpreting the plot. The range-bearing projector (plotting light) is mounted on the pencil carrier for use in conjunction with the auxiliary plotting board to indicate the (own) ship's position at all times.

The pencil carrier is mounted on ball bearing rollers that travel in grooves provided in two supports located on either side of the cross screw (fig. 8–7, A). These supports are part of the pencil carriage assembly and are therefore independent of the cross screw. Thus, the only contact the pencil carrier makes with the cross screw is through the threaded nut that converts the rotary motion of the cross screw into linear motion of the pencil and range-bearing projector.

The pencil can be set to any position within 0.1 in. of a designated point by two operating levers that actuate the quick-release nuts that run against the cross screw drive and the lead screw drive. These levers can be reached either through the side access doors in the DRT case, or by lifting the plotting board cover.

Two reset handwheels are provided for more precise setting of the pencil than to 0.1 in. (fig. 8–6). The reset handwheel mounted adjacent to the tracking-mechanism end of the case moves the pencil carrier along the cross-screw axis; whereas, the reset handwheel mounted at the chart-board end of the case moves the entire carriage assembly along the lead-screw axis.

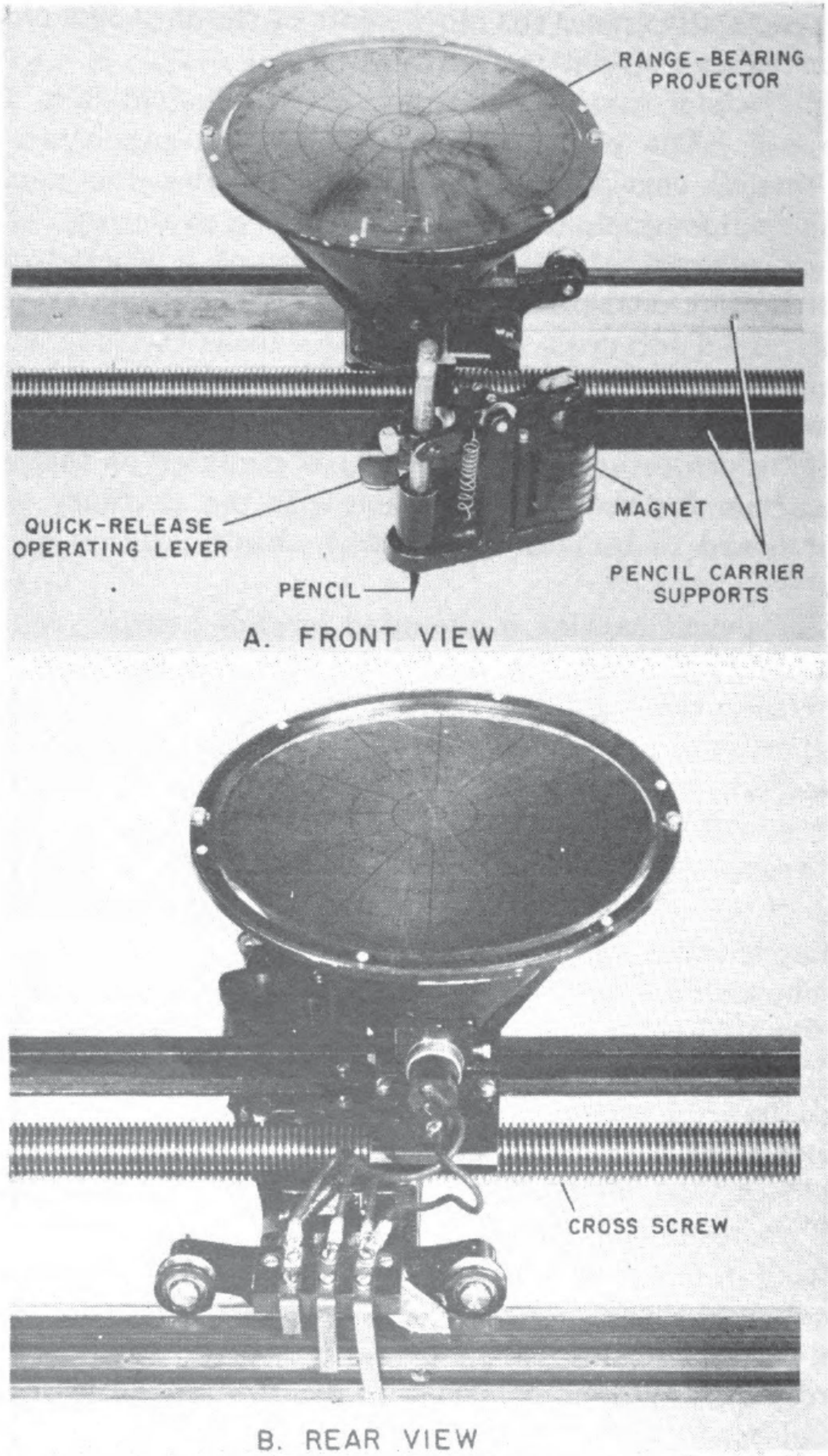


Figure 8–7.—DRT pencil carrier assembly.

The pencil magnet and the range-bearing projector light are connected to three sliding contacts (on the pencil carrier) that bear on a three-bus trolley circuit mounted on one of the pencil-carrier supports (fig. 8–7, B). The third bus is provided so that the pencil magnet and the range-bearing projector light can be used separately or simultaneously. Three brushes, located at the end of the three-bus trolley circuit opposite the bevel gears, bear on three stationary contact rails that are supplied with the ship's 120-volt, d-c power.

General illumination for the DRT is provided by lamps located inside the chart-board and the tracking-mechanism areas. The lighting supply, which can be either a-c or d-c, is connected to a terminal block mounted on the partition between the chart board and tracking mechanism. A variable resistor in series with this circuit controls the intensity of illumination.

AUXILIARY PLOTTING BOARD.—The auxiliary plotting board is a large glass surface mounted in a frame that is hinged to the DRT case (fig. 8–5). This plotting surface is furnished in conjunction with the DRT for plotting ranges and bearings of surface targets obtained from points along the (own) ship's course. It consists of a (1) flush top plotting surface to facilitate the use of a drafting machine (universal), and (2) range-bearing projector assembly mounted on the pencil carrier.

The range-bearing projector includes a light that projects an image on an appropriate chart placed on the plotting board. (Fig. 8–7.) This image consists of five uniformly spaced concentric circles with a dot in the center of the innermost circle denoting the (own) ship's position. The plotting scale must be the same as the tracking scale for which the tracking mechanism is adjusted.

The range and bearing of a target with respect to the (own) ship is plotted from the center dot of the projected image. If the plotted radius is less than 5 in., the range

and bearing will fall within the projected area. However, if the plotted radius exceeds 5 in., it is necessary to use a drafting machine.

The drafting machine is mounted on the glass plotting surface. It consists of a range ruler mounted from the center of a compass rose that is attached to a linked arm, and can be moved to any position on the plotting board. The range ruler can be set on any required bearing and when locked in place will remain on the same bearing irrespective of the movement of the compass rose.

OPERATION

The wiring diagram of the dead reckoning system is illustrated in figure 8–8 on pages 354 and 355. This system includes the (1) distance transmitter circuits, $2Y$; (2) course followup circuits, LC; (3) step transmitter circuits, $1TL$; and (4) pencil-magnet and projector-light circuits.

The DRE switch on the repeater panel is an ON-OFF switch. When this switch is closed, the rotor of the input course synchro receiver and the course followup motor are energized from the ship's single-phase, 120-volt, 60-cycle power supply; the 1-speed transmitter on the master compass provides an indication of the ship's course; the underwater log transmitter provides an indication of the ship's distance; and the step transmitters, step receivers, and pencil-magnet circuit are energized from the ship's d-c, 120-volt power supply.

DISTANCE TRANSMITTER CIRCUITS.—The input to the log distance transmitter circuits of the dead reckoning equipment is fed from the log distance transmitter to the DRE switch on the repeater panel (fig. 8–8). When this switch is closed, the stator leads, $S1$, $S2$, and $S3$, of the log distance transmitter are connected respectively to the terminals, $2Y301$, $2Y302$, and $2Y303$, on the repeater panel. These terminals are connected to the terminals, $2Y1$, $2Y2$, and $2Y3$, respectively, in the DRA.

The distance input receiver, *G*, in the DRA is a differential-type synchro having wye-connected stator windings and wye-connected rotor windings. The rotor leads, *R*1, *R*2, and *R*3, of this differential synchro receiver are connected, respectively, to the stator leads, *S*1, *S*2, and *S*3, of the log distance transmitter. The stator leads, *F*1, *F*2, and *F*3, of the differential synchro receiver (*F*1 and *F*3 connected together) are connected respectively to the rotor leads, *R*1 and *R*2, of the log distance transmitter, which is energized through the terminals, 2*Y* and 2*YY*, in the DRA from the ship's single-phase, 120-volt, 60-cycle power. This arrangement provides the necessary field excitation to produce motor torque so that the receiver matches the rotation of the log distance transmitter. The differential synchro receiver is employed instead of a conventional synchro receiver to obtain more reliable operation. If the primary power supply to the synchro differential receiver should fail, the torque and output would drop to values insufficient to operate the receiver; whereas, in an ordinary synchro receiver, the salient pole rotor might develop sufficient torque to lock in at either 0° or 180°. Thus, the system might operate with an error of 180°.

COURSE FOLLOWUP CIRCUITS.—The input to the course followup circuits of the dead reckoning equipment is fed from the 1-speed transmitter on the master compass to the DRE switch on the repeater panel (fig. 8–8). When this switch is closed, the 1-speed transmitter stator leads, *S*1, *S*2, and *S*3, are connected to the terminals, *LC*131, *LC*132, and *LC*133, in the DRA. These terminals are connected respectively, to the stator leads, *S*1, *S*2, and *S*3, of the course synchro receiver, V, in the DRA. The rotor leads, R1 and R2, of this course synchro receiver are connected, respectively, to the terminals, LC130 and LCC130 (in the DRA), which are energized from the ship's single-phase, 120-volt, 60-cycle power through the DRE switch on the repeater panel. An overload relay in the stator

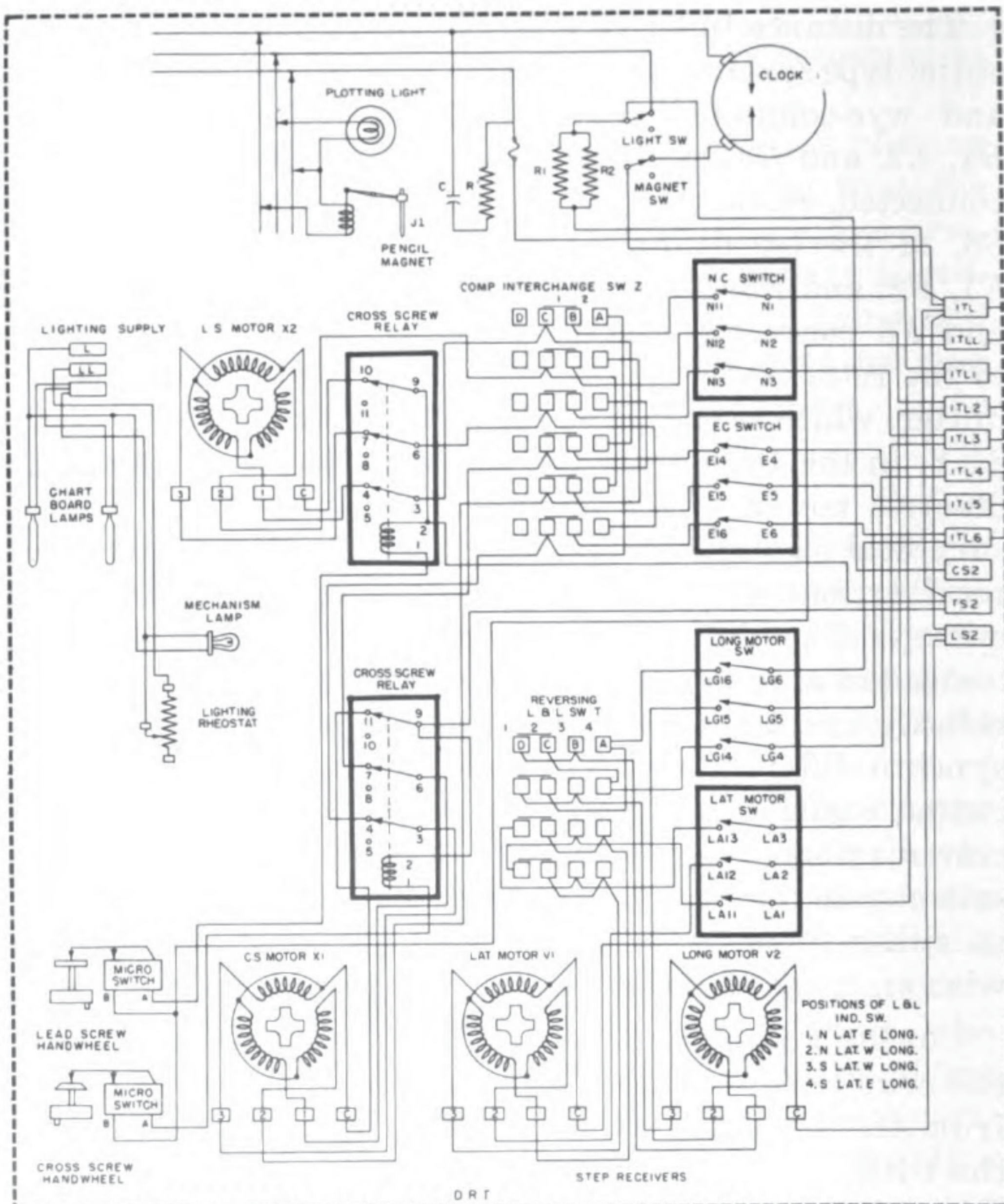


Figure 8—8.—Dead reckoning system wiring diagram.

circuit between the DRE switch and the fuses on the repeater panel will indicate improper functioning of the course input synchro receiver, V, in the DRA by lighting a signal light on the repeater panel.

The course followup motor, *U*, in the DRA is an a-c commutator-type series motor. It is energized from terminals *LC*130 and *LCC*130. Terminal *LC*130 is connected to the contact arm mounted on the rotor shaft of

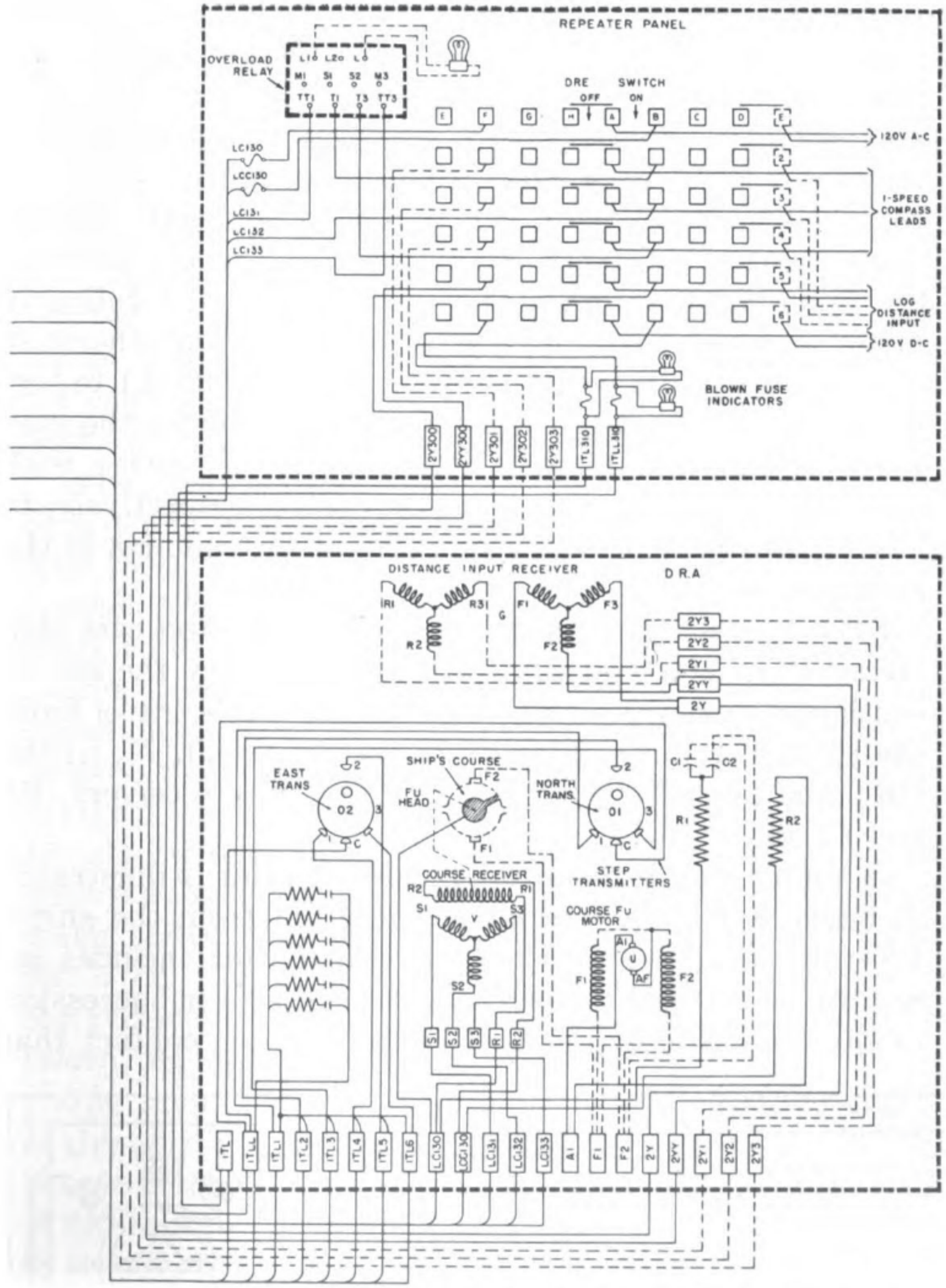


Figure 8–8.—Dead reckoning system wiring diagram—Continued.

the course synchro receiver, *V*. This arm can contact either split ring segment *F*1 or *F*2 in the followup head, depending on the direction of rotation of the course followup motor, *U*. These ring segments are connected,

respectively, to the field terminals, $F1$ and $F2$, of the course followup motor. The motor field windings are arranged so that when the contact arm is on one split ring segment, current flows through one winding and the motor turns in one direction. Conversely, when the contact arm is on the other split ring segment, current flows through the other winding and the motor turns in the opposite direction. The armature of the followup motor is in series with the energized field. The other side of the armature is connected through terminal $A1$ to terminal $LCC130$ through $R2$. Resistor $R2$ limits the current through the motor. Resistor $R1$, in series with capacitors $C1$ and $C2$ that are connected, respectively, to leads $F1$ and $F2$, prevents sparking at the contacts in the split ring assembly.

STEP TRANSMITTER CIRCUITS.—The north and east step transmitters, O1 and O2, in the DRA convey the north-south and east-west components of the ship's travel from the roller carriages, $P1$ and $P2$, to the pencil, $J1$, in the DRT and to the latitude and longitude dial receivers, $V1$ and $V2$, in the DRI.

A simple step transmitter-receiver circuit is illustrated in figure 8–9. The circuit is energized from the ship's 120-volt, d-c power. The step transmitter includes an eccentric arranged to operate three contacts in succession to close one side of the line, and a common contact that

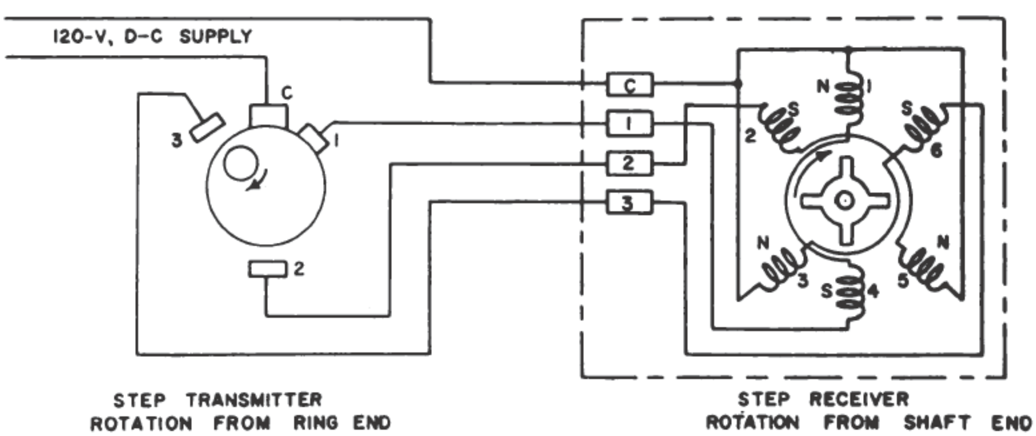


Figure 8—9.—Step transmitter-receiver circuit.

remains closed to complete the circuit. These three contacts energize coils in the step receiver in a definite sequence to cause the receiver rotor to rotate an amount proportional to the rotation of the transmitter. The rotor has four salient poles without windings.

The three transmitter contacts, 1, 2, and 3, are spaced 120° apart. Each is adjusted to make contact during 180° of the revolution of the eccentric to allow a 60° overlap in the closing of adjacent contacts. Each transmitter contact is connected to a pair of diametrically opposite coils in the six-pole step receiver.

When transmitter contact 1 closes to energize receiver coils 1 and 4, the closest pair of armature poles line up with these coils. Transmitter contact 2 closes 60° before contact 1 opens and energizes receiver coils 2 and 5 to make coils 1 and 2 opposite in polarity. This condition causes the receiver armature to rotate 15° in a clockwise direction, tending to line up the closest pair of adjacent poles with the axes of coils 1 and 2. Next, transmitter contact 1 opens and the receiver armature rotates another 15° clockwise to line up the closest pair of armature poles with the axes of coils 2 and 5. A similar sequence occurs when transmitter contact 3 closes and contact 2 opens 60° later. Thus, a 60° rotation of the transmitter causes the receiver to rotate 15°, resulting in a 4 to 1 ratio between the revolutions of the transmitter and receiver.

The step transmitter circuits of the dead reckoning equipment are supplied from the ship's 120-volt, d-c power to the DRE switch on the repeater panel (fig. 8–8). When this switch is closed, 120-volt, d-c power is supplied to terminals 1*TL*310 and 1*TLL*310 on the repeater panel. These terminals are connected to terminals 1*TL* and 1*TLL* respectively, in the DRA. Terminal 1*TLL* is connected to the common terminal, *C*, of both the north and east transmitters, 01 and 02. The return circuits from the transmitter contacts are to terminals 1*TL*1 to 1*TL*6, inclusive. These six transmitter terminals are connected to a re-

sistance and capacitor bank that has a common return to terminal 1*TLL*. This resistance-capacitance bank is provided to prevent sparking of the transmitter contacts.

The DRA terminals, 1*TL*, 1*TLL*, and 1*TL*1 to 1*TL*6, inclusive, are connected to similar marked terminals in the DRT (fig. 8–8). The cross screw and lead screw receivers, *X*1 and *X*2, are connected to the terminals, 1*TL*1, to 1*TL*6, inclusive, through the component interchange switch, *Z*. Terminals 1*TL*1, 1*TL*2, and 1*TL*3 provide the north-south components of the ship's travel, and terminals 1*TL*4, 1*TL*5, and 1*TL*6 provide the east-west components of the ship's travel. The common terminals, *C*, of both receivers *X*1 and *X*2 are connected to terminal 1*TL* through terminal *TS*2 in the DRT.

A relay in series with each of the receivers, *X*1 and *X*2, is energized from terminals 1*TL* and 1*TLL* with the d-c supply through microswitches mounted adjacent to the cross screw and lead screw reset handwheels. These relays are provided to automatically open the circuits of the pencil-drive receivers when using the reset handwheels. When either handwheel is operated, the thrust required to mesh the reset gears will close the microswitch in the circuit of the associated relay coil. This action causes the relay armature to open the contacts in series with the associated pencil-drive receiver.

The latitude receiver, *V*1, connected to terminals 1*TL*1, 1*TL*2, and 1*TL*3, and the longitude receiver, *V*2, connected to terminals 1*TL*4, 1*TL*5, and 1*TL*6 are connected through the (dial) reversing switch, *T*. The common terminal, *C*, of both the latitude and longitude receivers is connected to terminal 1*TL* through terminal *LS*2.

It is usually preferable to operate the DRT component interchange switch, *Z*, in position 2. In this position the north component actuates the cross screw receiver, *X*1, and the east component actuates the lead screw receiver, *X*2. Thus, as the ship travels in a northerly direction, the pencil will move away from the fluted-shaft side of the

case. Conversely, as the ship travels in an easterly direction, the entire pencil carriage assembly will move toward the tracking-mechanism end of the case.

In some installations it may be preferable to plot northerly travel of the ship along the lead screw axis. This is accomplished by setting the component interchange switch, Z, in position 1 to shift the plotting axes 90° counterclockwise. In this position the north component actuates the lead screw receiver, $X2$, and the east component actuates the cross screw receiver, $X1$. In either position the common terminal, C, of the receivers is connected to the $1TL$ terminal of the d-c supply through the respective relays.

Four 3-pole switches are provided in the receiver circuits (fig. 8–8) so that the receivers, $X1$, $X2$, $V1$, or $V2$, can be turned on or off independently while the equipment is in operation.

PENCIL-MAGNET AND PROJECTOR-LIGHT CIRCUITS.—The pencil-magnet and range-bearing projector-light circuits are energized from the ship's 120-volt, d-c power through terminals $1TL$, $1TLL$, and $CS2$ in the DRT (fig. 8–8).

When the pencil-magnet switch is closed, the circuit from terminal $1TL$ includes the magnet switch, clock, pencil magnet, fuse, and terminal $1TLL$. A capacitor, C, and resistor, R, that are connected across the magnet coil reduce sparking at the clock contacts.

When the light switch is closed, the circuit from terminal $1TL$ includes the parallel-connected resistors, $R1$ and $R2$, the light switch, the plotting light, the fuse, and terminal $1TLL$.

When the dead reckoning system is placed in operation, all switches should be in the OFF position, and the minute dials of the latitude and longitude dials of the DRT should be set to indicate the latitude and longitude of the ship. The latitude and longitude receiver switches should be turned to the ON position.

An appropriate chart on which the ship's course is to be plotted is tacked on the chart board and the desired ref-

erence lines are drawn. The course to be plotted should be considered, and the pencil should be placed so that it will not run off the chart on one side and leave a large unused section on the other side of the chart. The pencil is located by disengaging the clasp nuts on the pencil carriage and moving the pencil to the desired location. The north and east component receiver switches are now turned to the ON position.

The miles-per-inch setting of the DRT, for both the north and east components, should be adjusted to a value consistent with the length of the course to be plotted and the space available on the chart. Both settings should be adjusted to the same miles-per-inch scale to avoid the necessity of computing the number of miles for a given course.

The latitude and longitude (dial) reversing switch, *T*, of the DRT is set to the proper earth's quadrant in which the ship is operating. The latitude and longitude receivers will rotate in the proper direction, causing the latitude and longitude dials to indicate correctly. The proper position of this switch must be selected when crossing the equator, the 0° meridian, or the 180° meridian.

The component interchange switch, *Z*, of the DRT is set to the desired plotting axes as indicated on the nameplate under the switch handle. As previously stated, this switch provides for shifting the plotting axes at right angles to each other to orient the north in either of the two available directions on the chart board.

The clock switch of the DRT can be turned to the OFF or ON position, depending on whether or not it is desired to plot the course with a time element.

When the DRE switch is turned to the ON position the course receiver takes its proper position, and the followup motor brings the crank arms to their proper position. The step receivers in the DRT and the distance input receiver in the DRA revolve in synchronism with their respective transmitters.

QUIZ

1. What is the function of the dead reckoning system?
2. (a) What two components are computed mechanically to indicate continuously the ship's latitude and longitude? (b) From what sources are these components received?
3. Name the three components that comprise the dead reckoning system.
4. Name the two inputs to the dead reckoning analyzer.
5. The DRA combines its two inputs into what two distance components?
6. Name the three principal components that comprise the DRA.

REFERRING TO FIGURE 8–3 FOR QUESTIONS 7 THROUGH 9:

7. What is the function of the distance converter in the DRA?
8. (a) How are the roller carriages positioned in the DRA? (b) To what speed component is the speed of $L1$ proportional? (c) To what speed component is the speed of $L2$ proportional?
9. (a) What is the position of the speed rollers, $L1$ and $L2$, on a north-south course? (b) For this condition, what is the relative speed of the north speed roller, $L1$? (c) What is the relative speed of the east speed roller, $L2$?
10. Where is the DRI located in the dead reckoning system?
11. Name the three principal components of the DRI.
12. (1) Name the two inputs of the DRI and (2) the components that these inputs drive.
13. What is the purpose of the latitude and longitude indicator switch?
14. Why is the latitude correction mechanism provided in the DRI?
15. Name the three principal components of the DRT.
16. (1) Name the two inputs to the DRT and (2) the components that these inputs drive.
17. What are the two principal assemblies of the tracking mechanism in the DRT?
18. What is the purpose of the variable speed mechanism and gear shift assembly in the cross- and lead-screw drive unit assemblies?
19. What is the purpose of the component tracking (interchange) switch in the DRT?

20. Rotation of the lead screw in the DRT moves what assembly in which direction?

21. Rotation of the cross screw in the DRT moves what assembly in which direction?

22. To what components of the ship's travel are the vertical and horizontal movements of the pencil in the DRT proportional?

23. Where is the chart located in the DRT?

24. Name the three principal components of the pencil-carrier assembly.

25. How is the pencil magnet actuated?

26. What is the purpose of the range-bearing projector mounted on the pencil carrier?

27. What is the purpose of the auxiliary plotting board?

28. What is the purpose of the light in the range-bearing projector?

29. How is the image of the range-bearing projector used?

CHAPTER 9

DIAL TELEPHONE RELAYS AND SWITCHES

The remaining chapters of this training course describe in considerable detail the dial telephone system used aboard ship. The system is analyzed in terms of components, functions, and detailed circuitry. At this point, it is desirable to review the preliminary information concerning telephones in the *I. C. Electrician 3* and the *I. C. Electrician 2* training courses.

The sound-powered telephone system is discussed in *I. C. Electrician 3,* NavPers 10555. This discussion includes the theory, principles, operation, and repair of sound-powered telephones. Also, the primary, auxiliary, and supplementary sound-powered telephone circuits are explained, including the switchboard, switchbox, and string-type circuits.

The dial telephone system is discussed in *I. C. Electrician 2,* NavPers 10556. This discussion consists of a general description of the divisions and functions of the equipment that comprise the dial telephone system. In addition to the general discussion of the system, the telephone instrument is described in detail, including the components, circuits, and operation.

This chapter is a continuation of the dial telephone system contained in *I. C. Electrician 2,* NavPers 10556. It includes a detailed description of telephone relays and switches that comprise the remotely controlled switching

mechanisms necessary to perform automatically the switching functions.

TELEPHONE SWITCHBOARD FUNCTIONS

To enable the telephone user to call any one of a large number of telephones, a telephone system must perform the function of switching, in addition to transmitting and receiving the electrical equivalent of sound waves and signaling the called station. The switching function can be accomplished manually by an operator at the switchboard in the exchange or automatically by remotely controlled switching mechanisms.

The common-battery telephone system (manual or automatic), as previously explained in the training course, *I. C. Electrician 2,* NavPers 10556, employs a battery that is located at the central exchange to supply the necessary current that operates all of the telephones in the system. The switchboard provides a means of interconnecting the line stations. Each telephone in the system is connected to the switchboard by one line. Provision is made at the switchboard for connecting any one telephone to any other telephone in the exchange.

A switchboard that is provided with one terminal, or jack, for each local line is called a NONMULTIPLE switchboard. This type of switchboard is limited to the size that permits the operator at the switchboard to reach every line terminal unless local, or transfer, trunks are provided.

A switchboard that is provided with two or more line terminals that are connected in multiple to each telephone line and arranged so that the operator at each switchboard can reach at least one jack for each line is called a MULTIPLE switchboard. Any pair of lines in the switchboard can be connected together and thus eliminate the necessity for transfer trunks.

The operation of a telephone switchboard requires the use of various types of auxiliary apparatus to perform

the many switching functions that are necessary for satisfactory telephone service.

Manual Switchboard

Although the manual switchboard is not installed aboard naval ships it is included here to introduce the basic principles of telephone switching. The manual switchboard includes line terminals, or jacks; line signal lamps; and switching mechanisms. The switching mechanisms comprise pairs of cords and plugs (with the associated talking and ringing keys), supervisory signal lamps, and operator's talking set.

The telephone lines terminate at the switchboard in 3-terminal jacks that have tip, ring, and sleeve connections. The tip and ring of the cord circuit carry the two line wires; whereas, the sleeve is a local control wire used for certain operations within the cord circuit.

A schematic diagram of a cord circuit for a manual multiple switchboard is illustrated in figure 9–1. The cord circuits in the manual exchange are provided to connect the calling telephone with the called telephone. Each cord circuit contains either a repeating coil or a retardation coil that prevents voice currents from flowing through the common battery, but allows these currents to flow in their respective cord circuits.

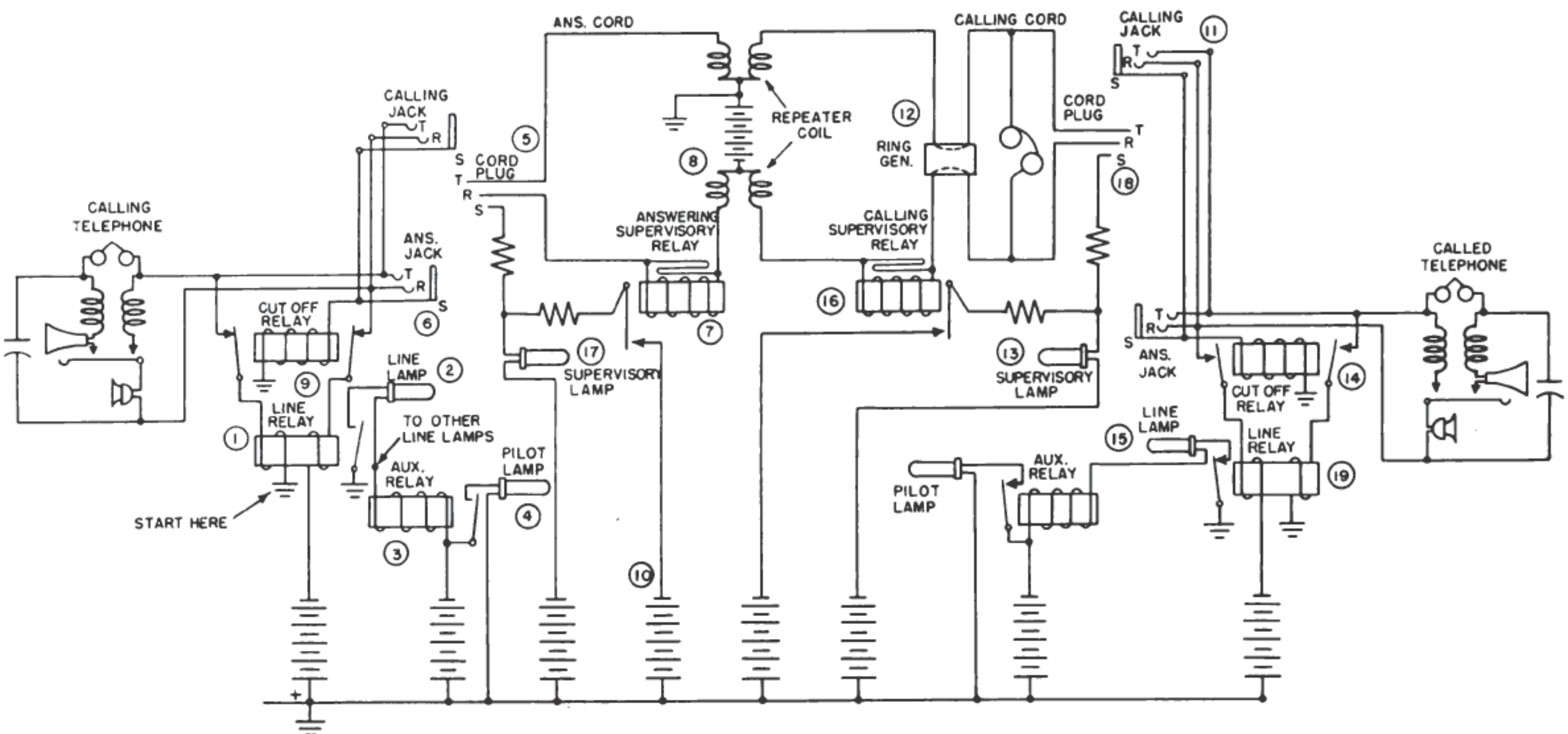
When the receiver is removed from the hookswitch at the calling telephone, the operating circuit is completed to the line relay ① from positive ground, through the hookswitch and transmitter, to negative battery at the exchange.

LINE RELAY ① OPERATES:

Completes the circuit to the line lamp ② at the switchboard, which, in turn, completes the operating circuit to the auxiliary relay ③.

AUXILIARY RELAY ③ OPERATES:

Completes the circuit to the pilot lamp ④, which remains lighted as long as there are any unanswered calls.



NOTE: THESE EXCHANGE BATTERIES (ACTUALLY ONE) ARE REDRAWN TO CLARIFY THE INDIVIDUAL CORD CIRCUITS

Figure 9—1.—Manual multiple switchboard cord circuit.

The switchboard operator answers the calling telephone by inserting the answering cord plug ⑤ in the answering jack ⑥. This action completes the operating circuit to the answering supervisory relay ⑦ from negative battery at the exchange, through the repeater coil ⑧, through the calling telephone circuit, and back to positive ground at the repeater coil.

ANSWERING SUPERVISORY RELAY ⑦ OPERATES:

Completes the operating circuit to the cutoff relay ⑨ from negative battery, through the sleeve, *S*, to positive ground.

CUTOFF RELAY ⑨ OPERATES:

Opens the circuit to the line relay ①.

LINE RELAY ① RESTORES:

Opens the circuit to the line lamp ② which opens the operating circuit of the auxiliary relay ③.

AUXILIARY RELAY ③ RESTORES:

Opens the circuit to the pilot lamp ④.

THE LINE AND PILOT LAMPS GO OUT.

The operator ascertains the desired number from the calling telephone and inserts the calling cord plug ⑱ in the calling jack ⑪ corresponding to the called telephone. The operator then completes the circuit from the ringing generator ⑫ at the exchange, over the tip, *T*, through the ringer and capacitor of the called telephone, back over the called telephone line, and back to the ringing generator. Also, a circuit is completed to the calling supervisory lamp ⑬ from negative battery at the exchange, over the sleeve, *S*, through the cutoff relay ⑭, and to positive ground.

CUTOFF RELAY ⑭ OPERATES:

Opens the operating circuit of the called line relay ⑲ to prevent the associated line lamp ⑮ from lighting when the receiver is removed from the hookswitch at the called telephone.

When the receiver is removed from the hookswitch at the called telephone to answer the call, the operating

circuit is completed to the calling supervisory relay ⑯ through the called telephone line.

CALLING SUPERVISORY RELAY ⑯ OPERATES:

1. Shunts out the supervisory lamp ⑬.
2. Holds cutoff relay ⑭ in the operated position from positive ground, over the sleeve, S, to negative battery.

The talking circuit is completed from the called telephone to the calling telephone through the associated lines, the cord circuit, and the repeater coil. Talking into the microphone of the calling telephone varies the resistance of the d-c loop and causes the current to pulsate in the two left-hand windings of the repeater coil ⑧. The changing flux in the repeater coil induces a signal voltage in the two right-hand windings that causes the current to vary in the receiver of the called telephone in accordance with the originating signal.

When either or both parties hang up, either or both supervisory relays ⑦ and ⑯ restore.

SUPERVISORY RELAYS ⑦ AND/OR ⑯ RESTORE:

1. Remove the shunt from the supervisory lamps ⑰ and/or ⑬ to light these lamps.

The operator moves the circuit cord plugs from the associated jacks and all relays release to normal.

The busy test is made before inserting the calling cord plug ⑱ in the calling jack ⑪ by touching the tip, *T*, of the calling plug ⑱ to the sleeve, *S*, of the called jack ⑪. If the called line is busy, the operating circuit is completed to the cutoff relay ⑭ by means of another telephone that is in multiple with the calling jack ⑪. When the busy test is made, a portion of the current through the cutoff relay ⑭ is shunted through a section of the repeater coil ⑧ to positive ground, causing a click in the operator's headset.

Automatic Switchboard

The automatic switchboard (fig. 9–2) is the switching center of the dial telephone system. This switchboard employs combinations of relays and switches to perform

the functions accomplished by the operator in the manual system. The automatic switchboard includes control circuits, line disconnect keys, a portion of the testing equipment, and most of the supervisory alarm signals. The most extensively used automatic switching equipment for

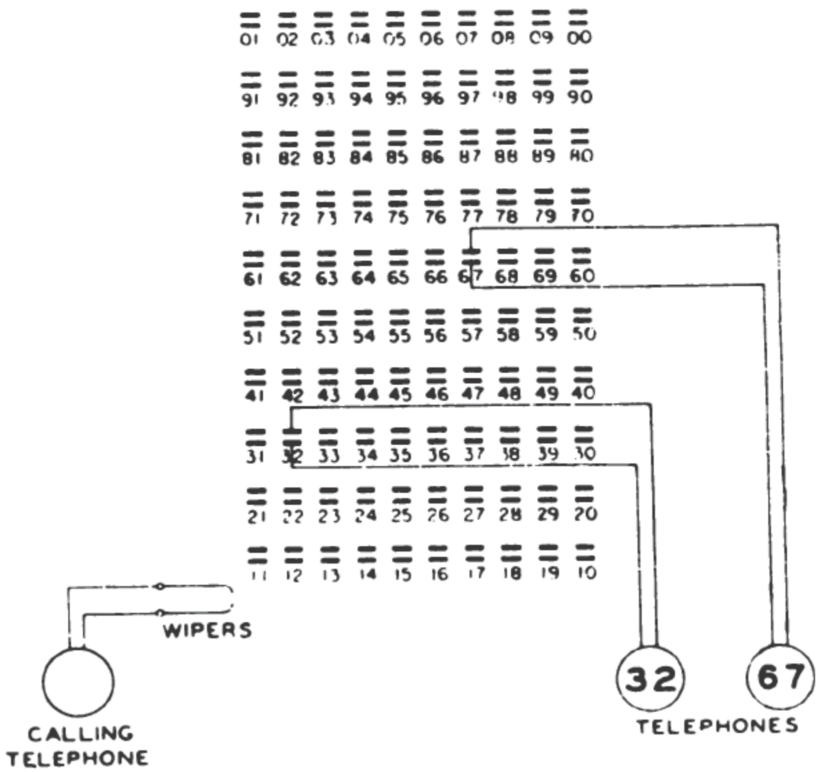


Figure 9—2.—Automatic multiple switchboard.

shipboard installations is the Strowger two-motion type of switch. The switching mechanisms used in this type of equipment operate on a step-by-step basis in synchronism with impulses that originate at the dial of the calling telephone, as previously explained in the training course, *I. C. Electrician 2.*

RELAYS

A relay is an electromagnetic device that is used to automatically open or close electrical circuits to other relays or pieces of equipment. Telephone relays include many types, such as line, cutoff, trunk, and supervisory relays.

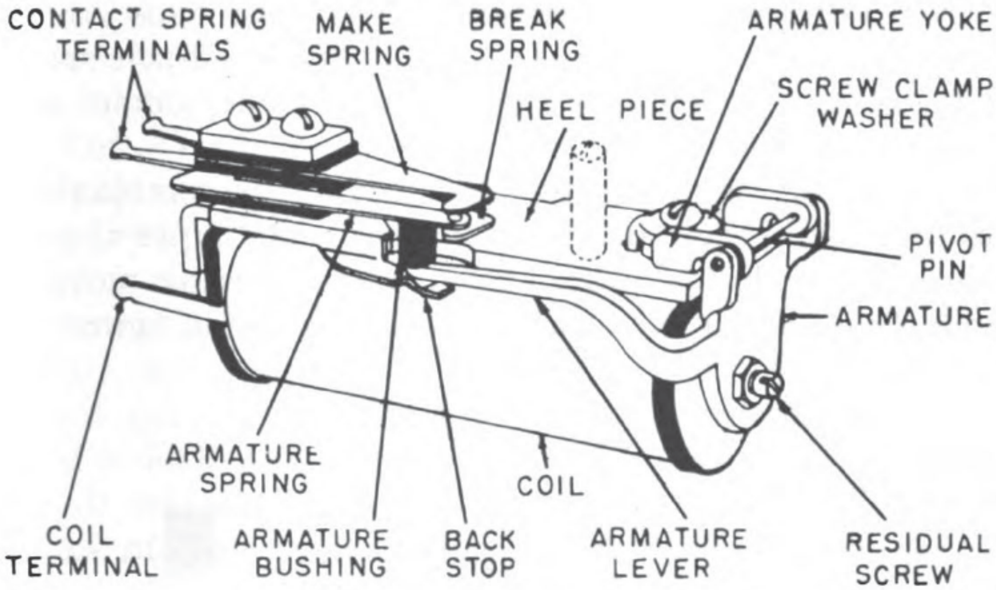
Construction

A standard horizontal relay is illustrated in figure 9–3. It consists of a (1) coil and core, (2) heelpiece, (3) armature, and (4) spring assembly (fig. 9–3, A). When current flows through the relay coil, a magnetic field is set up around the coil. The magnetic circuit includes the core, heelpiece, and armature (fig. 9–3, B). The magnetic field causes the armature to be attracted toward the core. The armature lever moves the armature springs, causing them to make or break contact with the contact springs, depending on the spring assembly. When there is no current flow through the relay coil, the armature restores (drops back), and the spring assembly returns to the normal position.

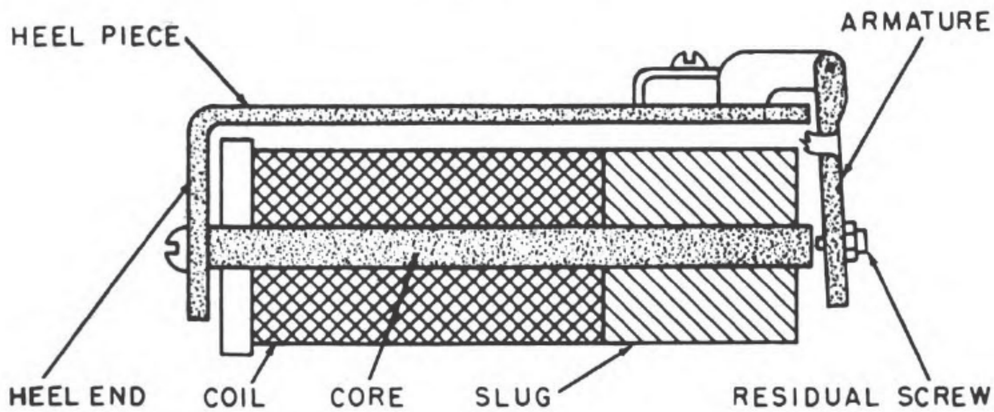
Coil.—The coil is wound on an iron core and is held in place by an insulating washer at each end of the core. The coil often consists of two or more separate windings, the ends of which are brought out to the coil terminals located at the rear end of the coil.

Heelpiece.—The heelpiece is an L-shaped piece of iron on which are mounted the coil, armature, and spring assembly. The coil is secured to the rear end of the heelpiece (fig. 9–3, B) by an iron screw so that the core and heelpiece are in direct contact to complete the magnetic circuit. Tapped holes are provided in the rear end of the heelpiece for attaching the relay to a mounting plate.

Armature.—The armature assembly consists of an armature, pivot pin, and yoke. The armature is pivoted at the open end of the yoke by the pivot pin. The yoke is secured to the front end of the heelpiece by a screw. The armature yoke and pivot pin are made of nonmagnetic material; whereas, the armature is made of zinc-plated magnetic material. The armature is provided with a nonmagnetic residual screw and a lock nut to adjust the gap between the armature and the core when the relay is closed. This residual screw prevents residual magnetism



A. PICTORIAL VIEW



B. CROSS-SECTIONAL VIEW

Figure 9—3.—Telephone relay.

from holding the armature in the operated position when the circuit to the relay coil is deenergized.

The armature lever is attached to the armature and operates the spring assembly. A bushing on the end of the armature lever insulates the lever from the spring with which it makes direct contact. When the armature is released, the armature lever rests against a back stop.

SPRING ASSEMBLY.—The spring assembly consists of a number of metallic springs that are insulated from each

other and from the heelpiece. The rear ends of the springs are connected to the circuit leads. Each spring has one or more metallic contacts that make contact with some other spring.

Relay springs are assembled in various combinations to fulfill specific circuit requirements. The types of relay springs are (1) make, or front, (2) armature, or movable, and (3) break, or back springs, as illustrated in figure 9–4.

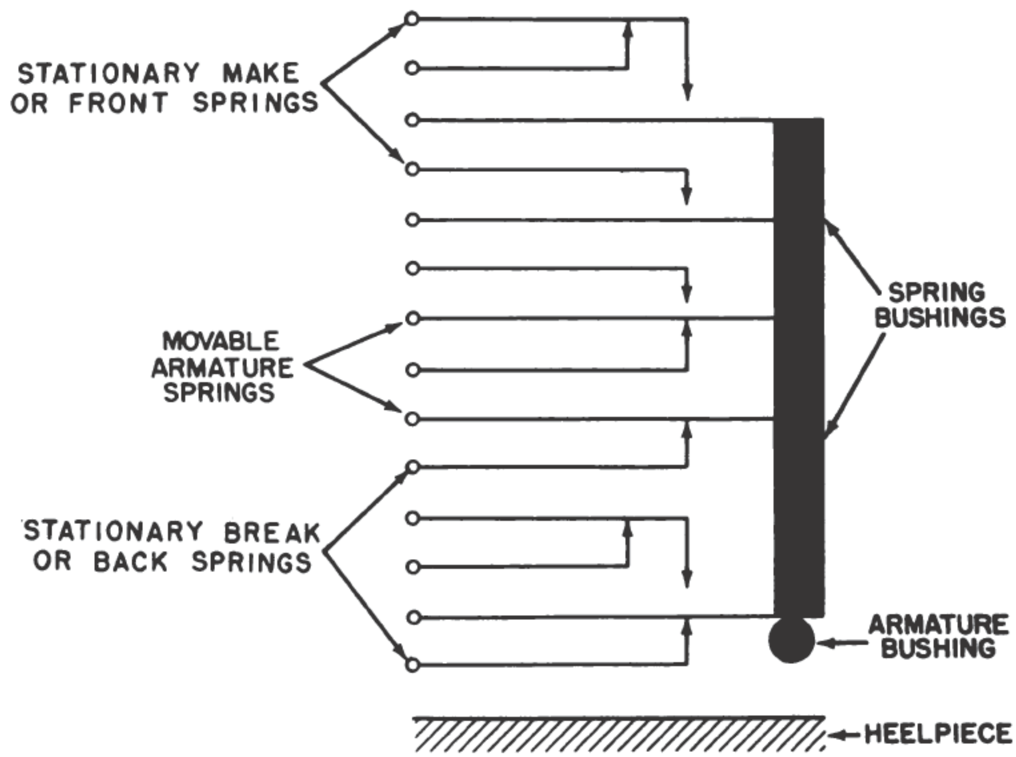


Figure 9—4.—Types of relay springs.

The armature springs are those springs that have tension toward the armature lever. When the relay is operated the make springs close their contacts, and the break springs open their contacts. When the circuit to the relay is deenergized, the armature is forced to release by the tension of the armature springs, and the break springs close their contacts. All other relay springs are stationary. Thus, all the armature springs move as a unit when the armature bushing, on the end of the armature

lever, pushes against the first armature spring. The motion is transmitted to the succeeding armature springs by the spring bushings.

The springs on a relay are called a SPRING PILEUP, and a relay can have a maximum of 13 springs in one pileup. If more than 13 springs are required, two pileups are used with a maximum of 10 springs in each pileup. Several different relay spring combinations are illustrated in figure 9–5. The basic types of spring assemblies are break springs, make springs, break-before-make springs, and make-before-break springs (fig. 9–5, A, B, C, and D).

All other relay spring assemblies consist of combinations of these four basic types. For example, an assembly comprising a break-before-make, a break, and a make combination is illustrated in figure 9–5, E; whereas, an assembly comprising a break-before-make-before break, a break-before-make, a break and a make combination is illustrated in figure 9–5, F.

Types

Telephone relays are designed to perform many different switching functions and are broadly classified as several general types, namely: (1) fast-acting, (2) slow-acting, and (3) a-c relays. The general types differ as to the number of windings in the coil and as to the spring pileups that are employed.

Relays are also designed as right mount or left mount according to the side of the frame on which they are mounted. When facing the armature end, if the spring pileup is on the upper right-hand side, it is a right-mount relay, and if the spring pileup is on the upper left-hand side, it is a left-mount relay. The physical position that the relay occupies on the frame also determines its letter designation.

FAST-ACTING RELAY.—A normal, or fast-acting relay (fig. 9–3) has an operating time of from 14 to 20 msec. This relay can be designed to have a time delay in either

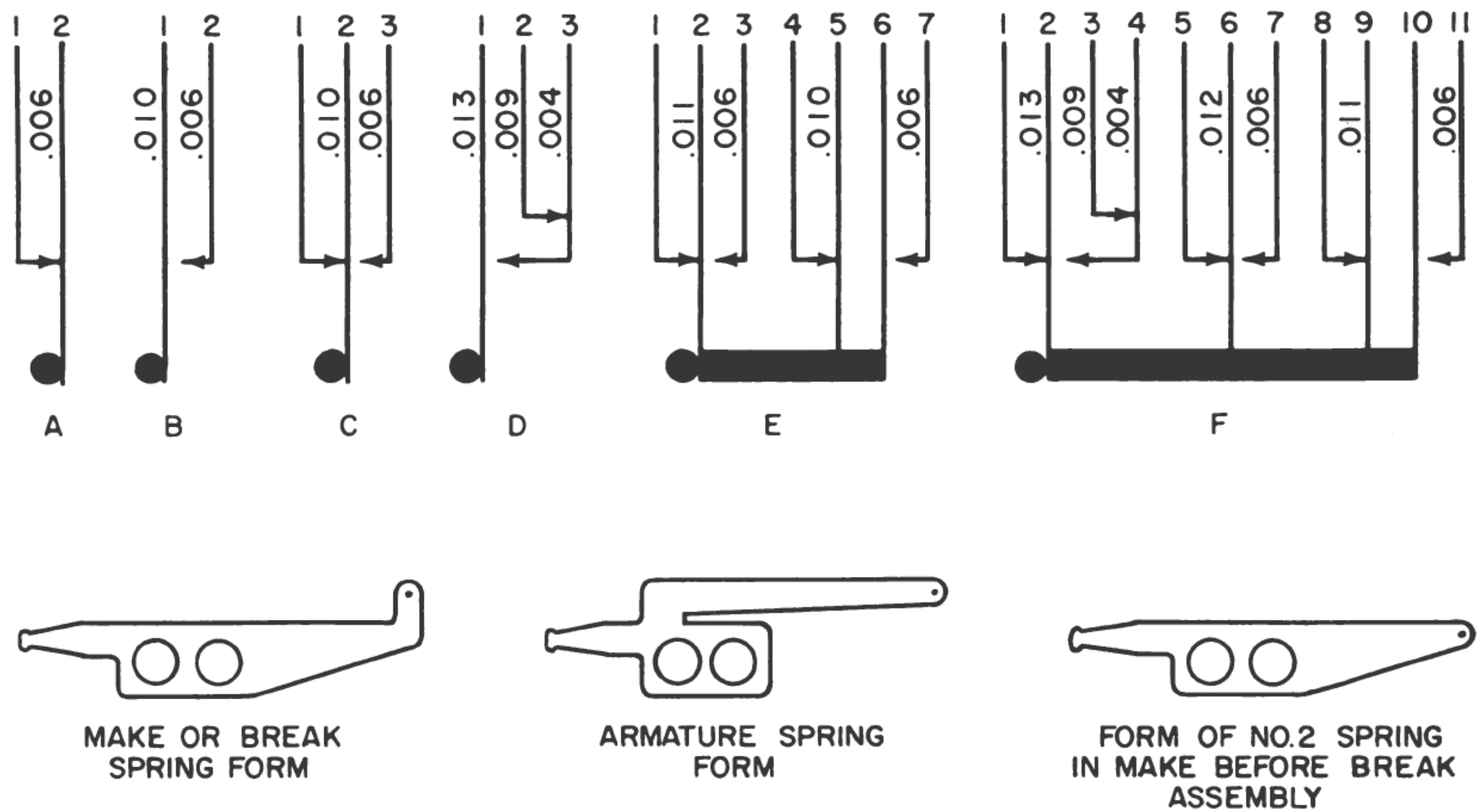


Figure 9—5.—Types of relay spring assemblies.

operating or releasing. Such a relay is classified as a slow-acting relay.

SLOW-ACTING RELAY.—A slow-acting relay can be either a slow-to-operate or a slow-to-release relay. In both relays the slow-acting feature is accomplished by placing a copper collar, or slug, around the core in such a position as to obtain the desired result.

A SLOW-TO-OPERATE relay (fig. 9–3, B) includes a copper collar, or slug, placed around the armature end of the core to delay the operation of the relay armature after the operating coil is energized. The slug functions as the low-resistance secondary of a transformer, the primary of which is the relay operating coil. When a voltage is applied to the primary, the current builds up in the coil. The magnetic field in the core builds up with the coil current and cuts through the copper slug. This action causes induced currents in the slug to flow in a direction that opposes the expanding field in the region around the air gap and thus delays the increase in the attracting force between the core and the armature. When the coil current reaches the steady state value and the core flux stops increasing, the induced current in the copper slug is reduced to zero, and the attractive force of the core on the armature overcomes the tension of the armature springs and operates the relay.

When the relay operating coil is deenergized, the field collapses rapidly because of the increase in resistance in the coil circuit when the circuit is opened. The induced current in the copper slug flows in a direction that opposes the decrease in field, causing a delay in the release of the relay. However, this delay is not as great as the delay in operating the relay because of the more rapid decrease in coil current.

A SLOW-TO-RELEASE relay includes a copper collar, or slug that is placed around the heelpiece end of the core, or a copper sleeve that is placed along the entire length of the core under the coil. With either of these arrangements the relay is fast to operate when energized, because

the growth of flux is not affected across the air gap between the coil and the armature. On the other hand, the relay is slow to release when deenergized, because the induced currents in the copper slug or sleeve delay the decay of flux across the air gap.

A-C RELAY.—An a-c relay includes a laminated iron core to minimize eddy currents and a shading coil on the armature end of the core to prevent the armature from vibrating. A capacitor is usually employed in series with the operating coil of this relay as a protection against any possible direct currents. A standard d-c relay with a rectifier can serve as a substitute when no a-c relay is available.

A few special relays are encountered, which are minor variations of the standard horizontal relay (fig. 9–3). The commonly used special relays are the (1) short-lever armature relay, (2) double armature relay, (3) two-step relay, (4) twin contact relay, and (5) type-Z relay.

The SHORT-LEVER ARMATURE relay employs a special armature construction in which the effective length of the armature is approximately the same as the length of the contact spring arm. In other words, the short-lever armature (1-to-1 ratio) eliminates the mechanical advantage of the contact springs acting on the standard armature (2.71-to-1 ratio), tending to release the armature to normal. Without this mechanical advantage, the springs are unable to release the armature until the magnetic field has decayed to a considerably lower value, resulting in a longer release delay. This type of relay is used in applications that require a release delay that is greater than can be obtained by means of a heelpiece-end copper collar or a copper sleeve.

The DOUBLE ARMATURE relay is equipped with an armature that has a lever arm on each side to operate two sets of contact springs.

The TWO-STEP relay does not operate all of the contact springs at the same time. For example, a line relay only

operates part of its springs when the headset is removed from the cradle switch at the calling station. After the calling line has been located by the finder and extended through the succeeding switch, other circuit conditions cause the line relay to operate the remainder of its contacts.

The TWIN-CONTACT relay is equipped with two contacts on each spring to obtain a greater current-carrying capacity than that provided by single contacts.

The TYPE-Z relay is designed to occupy a smaller space than the standard horizontal relay. The saving in space is achieved principally by locating the contact springs at the armature end of the heelpiece instead of at the mounting end, thereby permitting the use of a shorter heelpiece and coil.

Adjustments

Relay spring adjustments consist of (1) spring gaging, and (2) spring margining. The purpose of all relay adjustments is to obtain positive operation of the relay armature and to provide adequate pressure between the pairs of springs for proper closure of the electrical circuits.

SPRING GAGING.—Spring gaging is the positioning (bending) of the stationary springs so that the armature springs exert pressure against the break contacts when the relay is restored, and so that the armature springs exert pressure against the make contacts when the relay is operated.

The values of the air gaps for the various spring assemblies are specified on the relay adjustment sheet that is furnished with the equipment. For example, the values of the air gaps, which must exist between the residual screw and the core as the springs barely break or barely make contact, are indicated for the various assemblies of the relay shown in figure 9–5.

In the break assembly (fig. 9–5, A), the air gap is the distance between the residual screw in the armature and

the core as the springs barely break contact. This distance should be 0.006 in. and is obtained by adjusting the residual screw. In the make assembly (fig. 9–5, B), the contacts are adjusted until they barely make contact with an air gap of 0.006 in. Also, the distance between the residual screw and the core when the relay is released is called the armature STROKE. This distance should be 0.010 in. and is obtained by adjusting the armature back stop. Stroke values are necessary only for relays that do not have a break contact as the first spring in the assembly.

When the above adjustments are made, the air gaps are measured by inserting gages of proper thickness between the residual screw and the core. The values of the air gaps associated with the springs of the other assemblies (fig. 9–5, C, D, E, and F) control the operation of the springs with respect to the armature air gap for the assemblies previously described (fig. 9–5, A and B).

SPRING MARGINING.—Spring margining is the tensioning of the armature springs to provide satisfactory operation of the relay armature between two specified values of control-coil current. These values of current are the operate and nonoperate values that are listed on the relay adjustment sheet. The operate value is the minimum current at which the relay will operate, and the nonoperate value is the maximum current at which the relay will not operate. Margining is actually the measurement of the total resistance (load) offered by the tension in the springs to the operation of the armature. Hence, the springs must be adjusted to provide sufficient load when the specified nonoperate current is flowing in the relay coil so that the armature can not operate. This spring tension is utilized in exerting contact pressure between the armature springs and the back contact springs. However, the springs must not be adjusted to provide too great a load on the armature because the specified operate current must cause complete operation of the relay. The

specified operate and nonoperate values can be determined by a milliammeter or by connecting a known resistance in series with the relay coil and applying a known voltage to the circuit. However, when spring gaging has been performed correctly, it is seldom necesssary to perform spring margining tests.

SWITCHES

The switches employed in the automatic switchboard perform all of the switching functions accomplished by the cord circuits in the manual system. The different types of switches used in the shipboard automatic telephone system are usually the finder, connector, selector, and minor switches. The basic Strowger switch mechanism is a two-motion type of switch. It is utilized in the finder, connector, and selector switches with slight variations in the electrical and mechanical components.

Strowger Switch

The basic Strowger switch (fig. 9–6) consists of the (1) bank assembly, (2) switch mechanism, and (3) control relays. Other accessories (not shown) include the (1) switch jacks, (2) test jack, and (3) busy key. These components are assembled as a complete unit attached to a metal mounting base. The basic switch mechanism is on the base, and the control relays are mounted just above the switch mechanism. The banks associated with the switch are located below the bottom part of the base. A protective metal cover (not shown) fits over the front of the switch and rests on the lower part of the mounting base.

BANK ASSEMBLY.—The bank assembly to which the lines or trunks are terminated consists of two sets of banks fastened one above the other. The top and bottom banks are the private (control) and line banks, respectively. When a vertical bank is included in addition to the private and line banks, the switch is called a finder switch (fig. 9–6). The vertical bank is required only on finder switches.

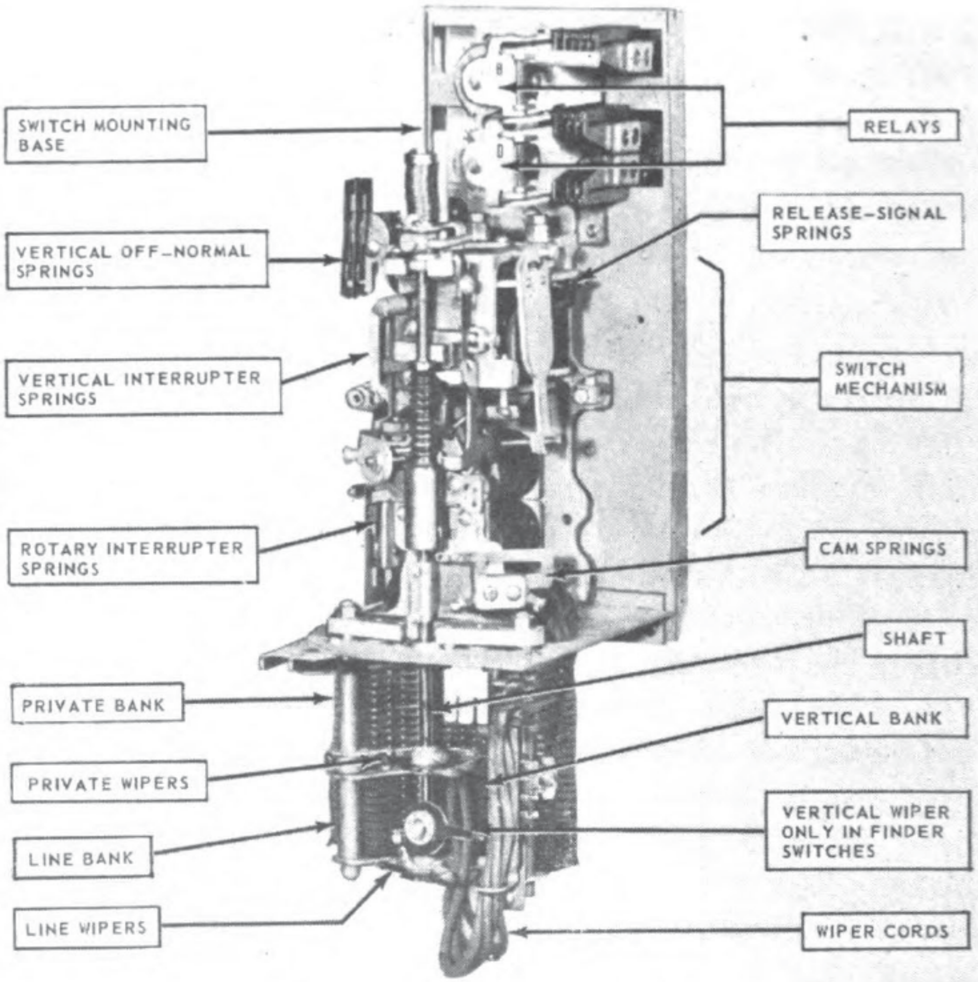


Figure 9—6.—Strowger switch.

The PRIVATE BANK and the LINE BANK consist of 100 sets of double contacts each. The sets of contacts are arranged in rows, 10 sets high and 10 sets wide. The 10 horizontal rows are called LEVELS. Each individual contact is insulated from the other contacts and is provided with a terminal, at the rear of the bank, to which is connected one of the line wires or trunk wires associated with the switch. The front ends of the contacts are shaped and arranged so that a set of spring wipers, attached to the shaft of the switch mechanism can come in contact and make connection with any set of contacts in the bank. There is one set of wipers for each bank. By means of the switch mechanism, the wipers can be raised vertically

to any level of horizontal contacts and then rotated horizontally over the level until the desired set of double contacts is reached.

In order for more than one call to pass to lines or trunks in the group at the same time, it is necessary that a number of switches have access to the same group of 100 lines (fig. 9–7). Hence, the corresponding contacts in the

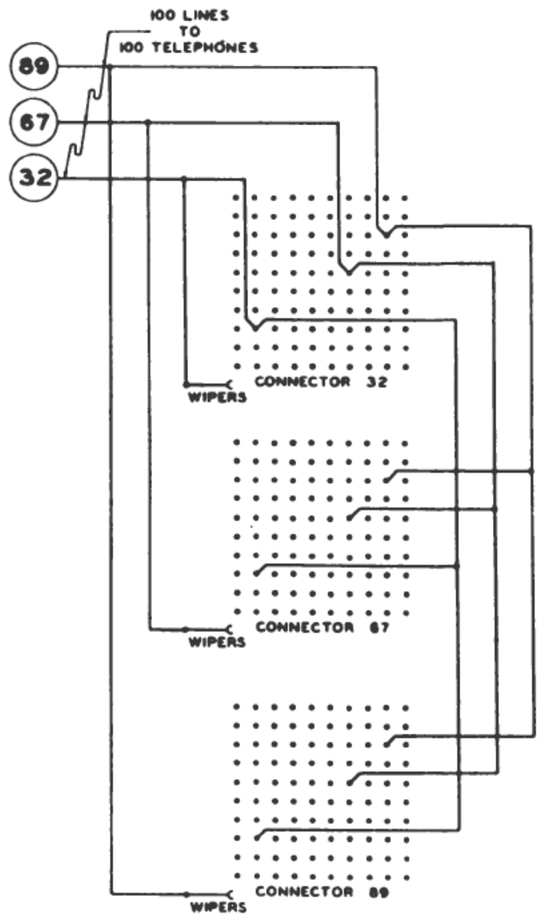


Figure 9—7.—Basic 100-line finder-connector system.

banks of a group of switches are multipled (connected together) so that any one individual line or trunk is connected in the banks of several switches and is not dependent on whether or not any one particular switch is busy. Thus, a line can be seized by any idle switch in the group. The switches are generally grouped on shelves. The switches of each shelf that have banks multipled together are connected to a terminal block.

The bottom contact of each pair of contacts in the upper (private) bank is called the C (control) contact. This contact is used in the control (seizure and release) circuit of the switch. When the switch is seized by a preceding switch, it is seized via the *C* lead. As soon as the seizure is completed, a holding circuit is established from the succeeding to the preceding switch via the *C* lead to hold the preceding switch operated until the succeeding switch releases. This circuit is described in detail in the chapter on the 100-line capacity dial telephone system.

The top contact of each pair of contacts in the upper (private) bank is called the EC (extra control) contact. This contact is used for some special service, such as the executive cut-in service.

The top and bottom contacts in the lower (line) bank are designated as the negative (−) and positive (+) contacts, respectively. These are the line contacts through which dialing and talking take place.

The VERTICAL BANK (finder switches only) consists of one vertical row, which has 11 contacts, one contact for the normal or bottom position and one contact for each of the 10 levels in the line bank. When the wiper is in the normal position, it rests against the bottom contact (dead contact) to keep the wiper mechanically in line with the contacts above. The vertical bank is used to eliminate the necessity for the finder to test each line in each level for a calling line. When the line relay of a calling line operates, the vertical contact of the level in which the calling line is located will be marked by having direct ground placed on it. Also, the line relay will mark the correct contact on the (vertical) level by placing negative battery (acting through the relay coil) on the contact. For example, if the calling line is connected to contact number 47, direct ground would be placed on the fourth level contact of the vertical bank, and negative battery would be placed on the seventh contact of the fourth level. The finder would step up four steps and in seven steps.

The WIPERS (fig. 9–6) are attached to the lower part of the switch shaft. The top and bottom sets of wipers are the private and line wipers, respectively. A vertical wiper is included if the switch is a finder switch.

Each set of wipers consists of two wiper springs (upper and lower) that are insulated from each other. When these wipers are stepped UP and IN, they make contact with the upper and lower contacts of the associated bank. The opposite ends of the wiper springs are connected to wiper cords. The wiper cords connect the corresponding wiper contacts of the private bank with those of the line bank (fig. 9–8).

The private and line wipers are in a vertical plane, parallel to each other. The line wiper is arranged so that when the private wiper is raised to the plane of any level

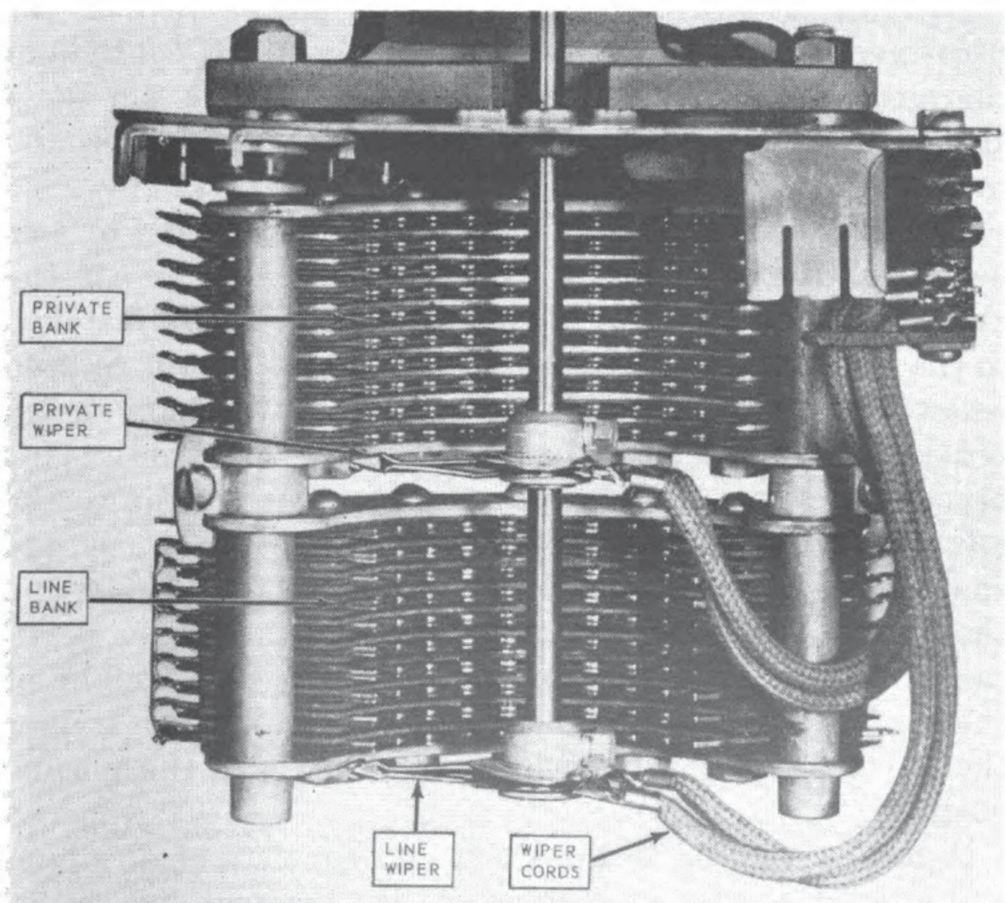


Figure 9—8.—Wiper cord schematic diagram.

of contacts in the private bank, the line wiper is raised to the plane of the corresponding level of contacts in the line bank. When the wipers are in their normal positions, they are one step below the first level of bank contacts and one step to the left of the first bank contact in the level. Hence, the shaft must take one vertical step to place the wipers in the horizontal plane of the first level, and so on. After the wipers have reached the desired level, the shaft must take one rotary step to place the wipers in contact with the first pair of contacts in the first level, and so on. The number of steps (vertical and rotary) necessary to reach a contact determines its number in the bank. For example, if three vertical steps and two rotary steps are required to reach a set of contacts, the contact number is 32 (the second contact in the third level).

SWITCH MECHANISM.—The switch mechanism of the Strowger switch is illustrated in figure 9–9. It consists of the mechanical components necessary to move the shaft and wiper assembly in a vertical and rotary direction and to return this assembly to the normal position.

The shaft of the switch mechanism is supported by two bearings, one at the top and one at the bottom of the switch frame. A shaft spring assembly, SS, is fastened to the upper end of the shaft. A normal stop pin, located below this spring assembly, rests against the shaft spring bracket when the shaft is in the normal position. This bracket prevents the shaft from swinging too far to the left because of the torque exerted on the shaft by the shaft spring. When the shaft is in the normal position, the normal stop pin rests on an arm that causes the vertical off-normal springs, VON, to operate. The weight of the shaft rests on the normal stop pin clamp, which strikes the upper shaft bearing when the shaft is in the normal position.

A hub is secured to the shaft and consists of an upper and a lower section that comprise the vertical and rotary ratchets, respectively. The vertical ratchet contains 10

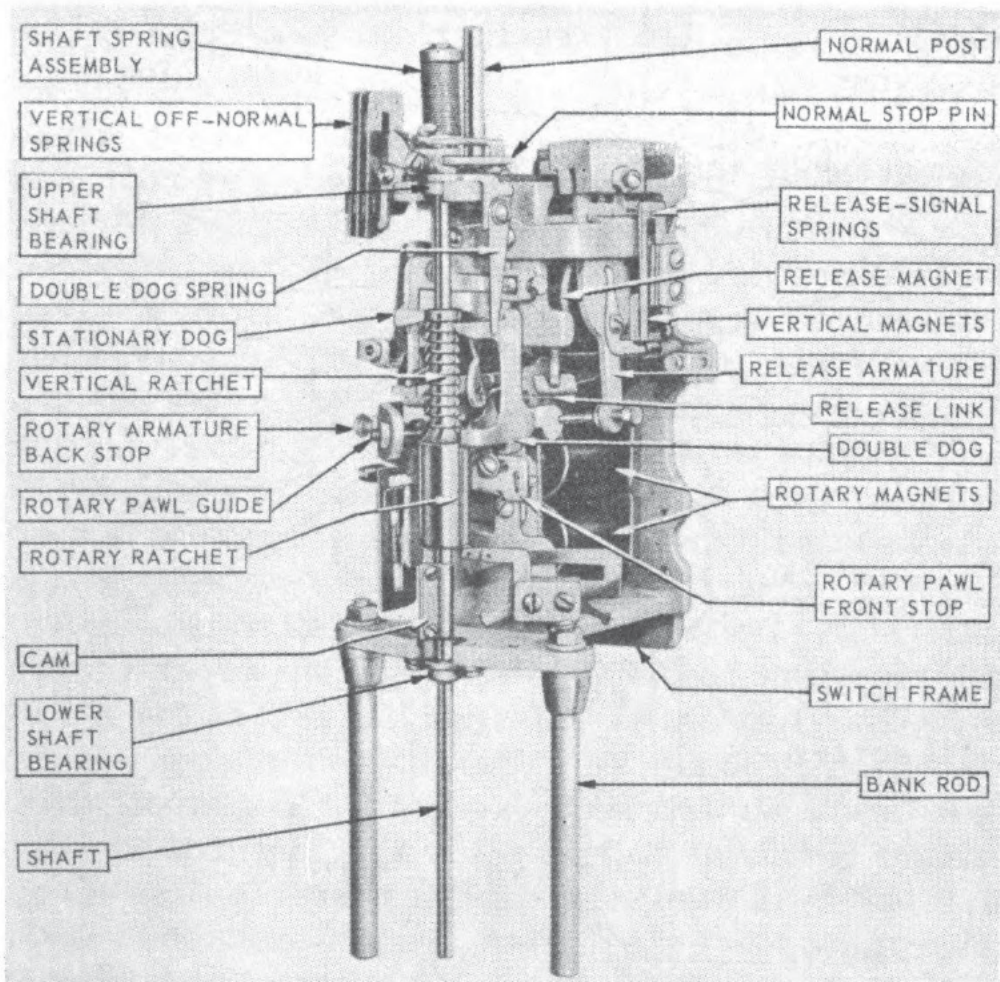


Figure 9—9.—Strowger switch mechanism.

horizontal teeth and is used for lifting the shaft. The rotary ratchet contains 18 vertical teeth and is used for rotating the shaft. A sleevelike cam is clamped on the shaft below the hub to operate the cam springs during the rotary movement of the shaft.

A single stationary dog, *SD*, and a double movable dog, *DD*, are provided for the operation of the ratchets. When the ratchets are moved off normal, the dogs engage the teeth and hold the ratchets in the last operated position. The stationary dog is used to hold the vertical ratchet up when the shaft is rotated. The double dog is used to (1) prevent the shaft from falling while it is being stepped vertically, (2) prevent the shaft from returning to

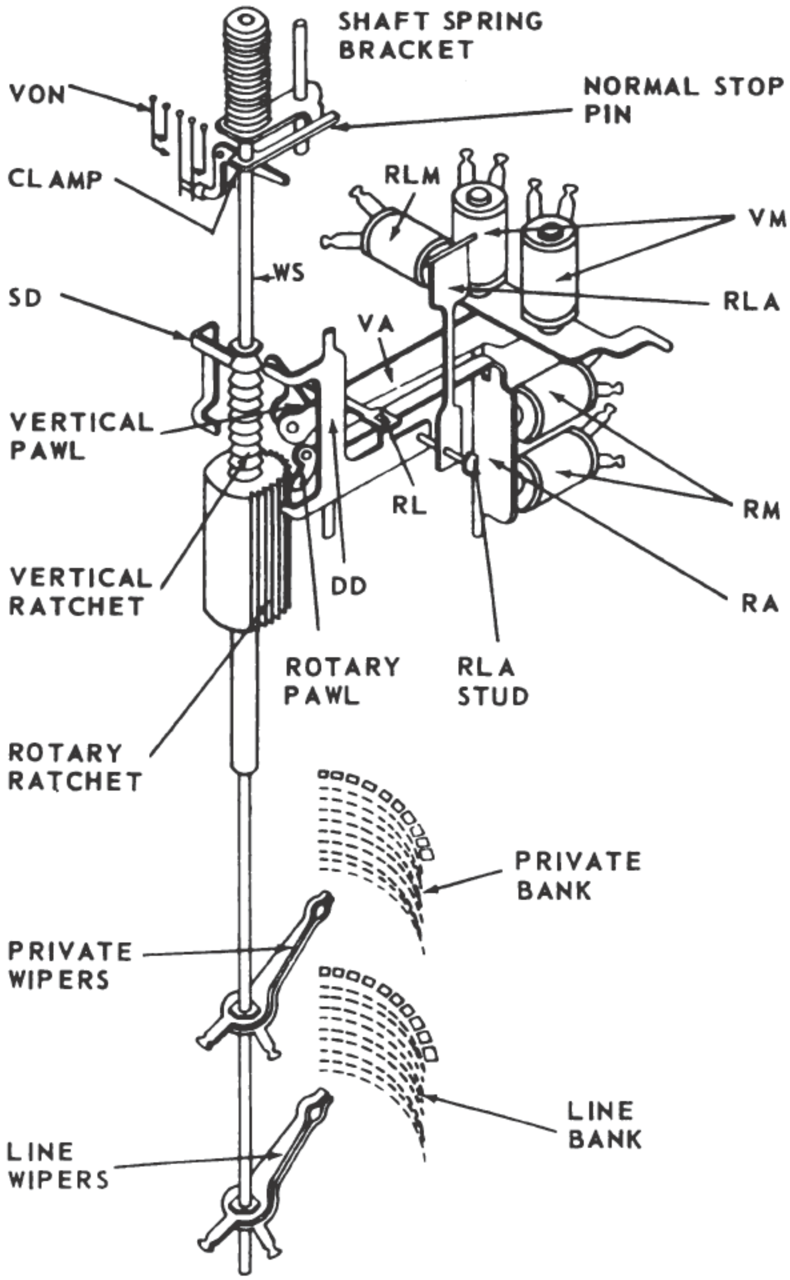


Figure 9—10.—Strowger switch schematic.

normal while it is being rotated horizontally, and (3) hold the rotary shaft in the last operated position when the rotation is completed.

As previously mentioned, the (1) vertical motion, (2) rotary motion, and (3) release action associated with the shaft of the Strowger switch are illustrated by the schematic diagram in figure 9–10.

The VERTICAL MOTION of the shaft is accomplished by relaying the dial impulses to the vertical magnets, VM (fig. 9–10). Each time the vertical magnets are energized, the vertical armature, VA, causes the vertical pawl to engage the teeth of the vertical ratchet and lift the shaft and wiper assembly, *WS*, one bank level. When the first series of dial impulses has ceased, the shaft must be stepped up so that the wipers are in line with the desired bank level. Each time the vertical magnets are deenergized, the vertical pawl is withdrawn from the vertical ratchet and the vertical tip (upper) of the double dog, DD, engages a tooth of the vertical ratchet to retain the shaft in the elevated position. The double dog is normally held clear of the vertical and rotary ratchets by means of a flat spring called the release link, RL.

A groove in the left side of the vertical ratchet (not shown) allows the ratchet to pass by the stationary dog, SD, during the vertical movement of the shaft. The stationary dog supports the weight of the shaft during the rotary movement. A bump (not shown) underneath each tooth on the right side of the vertical ratchet is engaged by the vertical tip of the double dog during vertical stepping. The stationary dog is adjusted so that as the bump moves off the vertical tip of the double dog on the first rotary step, the edge of that tooth (at the groove) passes onto the stationary dog without raising or lowering the shaft perceptibly. Hence, as soon as the bump on the underside of the tooth leaves the vertical tip of the double dog, there is a clearance between the double dog and the tooth, and the stationary dog supports the weight of the shaft.

The ROTARY MOTION of the shaft is accomplished by relaying the dial impulses to the rotary magnets, RM (fig. 9–10). Each time the rotary magnets are energized, the rotary armature, RA, causes the rotary pawl to engage the teeth of the rotary ratchet and rotate the shaft and the wiper assembly one step. When the first series of dial impulses has ceased, the shaft must be rotated in so that

the wipers are in contact with the desired pair of contacts in the selected bank level. Each time the rotary magnets are deenergized, the rotary pawl is withdrawn from the rotary ratchet and the rotary tip (lower) of the double dog engages a tooth in the rotary ratchet to retain the shaft in the rotated position.

When the rotary armature, RA, is fully operated, the shaft is forced around sufficiently to cause the rotary tip of the double dog to engage a tooth in the rotary ratchet. When the rotary armature is at normal, the armature rests against the rotary stop pin (not shown). This pin is adjusted so that the rotary pawl clears the rotary ratchet as the shaft is being stepped vertically or released. A flat spring is fastened to the armature and bears against an adjusting screw in the frame (not shown). This spring provides the necessary tension to restore the rotary armature to the normal position.

The RELEASE ACTION of the shaft is accomplished by relaying the dial impulses to the release magnet, RLM (fig. 9–10). When the release magnet is energized, the stud on the release magnet armature, RLA, presses against the double dog and causes it to withdraw from the vertical and rotary ratchets. A flat spring, *RL*, hooks over a projection (on the double dog) to retain the double dog in the normal, or disengaged position, with the vertical and rotary ratchets. In this position the helical spring, SS (shaft spring assembly), at the upper end of the shaft causes the shaft and wipers to rotate back and clear the bank. The stationary dog prevents the shaft from dropping while it is being returned to the rotary starting position until the groove (slot) in the vertical ratchet comes in contact with the stationary dog, at which time the shaft drops to its normal position.

The vertical, rotary, and release magnets are fast acting. They respond quickly when the coil circuits are energized or deenergized.

The spring assemblies provided in every Strowger switch are the (1) vertical-off-normal, (2) vertical inter-

rupter, and (3) release signal springs (fig. 9–6). The other spring assemblies, such as the rotary interrupter and cam springs, vary according to whether the switch is a finder, connector, or selector. The various spring assemblies carry contacts that are also concerned with the electrical circuits.

The VERTICAL-OFF-NORMAL springs, VON, are located in front of the associated vertical magnet (fig. 9–6). These springs are used to transfer the impulsing circuit from the vertical stepping to the rotary stepping, and to prepare the release circuit.

These springs are in one position when the switch shaft is at normal. When the shaft is lifted one step, the normal pin is lifted clear of the off-normal spring lever, and the moving springs restore against their associated back contact springs.

The VERTICAL and ROTARY INTERRUPTER springs (fig. 9–6) usually consist of two springs each. The moving spring of the assembly is operated by an arm that is part of the armature of the associated vertical or rotary magnet.

Interrupter springs are used in furnishing the impulses for automatic stepping of Strowger switches. Thus, a finder switch has both vertical and rotary interrupter springs, a selector switch has rotary interrupter springs for trunk hunting on the dialed level, and a connector switch has rotary interrupter springs for hunt-the-not-busy-line service. The interrupter springs are always located in front of the associated vertical or rotary magnet.

The RELEASE SIGNAL springs are usually provided with all Strowger switches (fig. 9–6). These springs are actuated by a lever attached to the release armature of the associated release magnet to restore the shaft to the normal position.

The CAM springs are located on the lower right-hand side of the switch mechanism frame (fig. 9–6). These

springs are operated by a cam clamped on the shaft below the rotary ratchet. The cam is usually adjusted to operate the springs on the eleventh rotary step, the point at which the wipers pass off the last contact on the level.

CONTROL RELAYS.—The relays that control the electrical circuits are located above the switch mechanism (fig. 9–6). These relays are mounted in two vertical rows with the associated spring assemblies toward the sides of the switch. The coil and spring terminals are brought out to the rear of the mounting base and connected to the various electrical circuits.

SWITCH JACKS.—The switch jacks (not shown) are mounted on a jack strip fastened to the rear of the switch frame. The jack strip contains from 16 to 32 jack springs that are insulated from each other and arranged to make contact with jack clips when the switch is jacked into place. If more than 32 jacks are required, two jack strips are provided, one mounted above the other. The various circuits entering or leaving the switch pass through the jacks so that it is not necessary to disconnect any wires when removing the switch from the mounting frame.

TEST JACK.—The number of test jacks (not shown) is determined by the particular type of Strowger switch. They are mounted on the right-hand side of the banks under the horizontal part of the mounting base. These jacks are used to test for proper operation or to monitor calls, and are employed with selector and connector switches.

BUSY KEY.—The busy key (not shown) is mounted on the left-hand side of the banks under the horizontal part of the mounting base. Busy keys are usually found on selector and connector switches. They are used to BUSY OUT a defective switch, and sometimes to busy out a switch for test purposes.

Finder Switch

The finder switch is often referred to as a nonnumerical type of switch because its operation is automatic and

not under the control of the dial impulses. When the handset of the calling telephone is removed from the cradle switch, the line relay of this telephone operates. This action causes the finder to find the line that demands service and to connect this line to an idle connector. The operation of the finder switch is controlled by the finder control and distributor relays. These relays control the vertical and rotary movements of the finder.

The major functions of the finder are to:

1. Elevate its wipers to the marked level.
2. Rotate its wipers into contact with the terminals of the calling line.
3. Cause the combination relay of the calling line to disconnect its winding from the line conductor.
4. Busy the calling line at the connector banks.
5. Extend the calling line to the connector switch.
6. Cause the finder control and distributor equipment to select the next idle finder for the succeeding call.
7. Release at the termination of the call.

Connector Switch

The connector switch is a numerical type of switch that makes the final connection to the called line under control of the impulses sent out by the dial of the calling telephone. This switch is similar to the finder switch, except that it is not provided with a vertical bank and wiper or vertical interrupter springs. It is equipped with rotary interrupter springs, which are used to accomplish the hunt-the-not-busy-line feature.

A connector switch can have as many as 13 relays mounted above the switch mechanism. These relays are necessary to perform many functions, such as testing the dialed line for busy, supplying transmission current to both the calling and called telephones, and providing executive cut-in service. Also, a minor switch (to be discussed later) is often mounted as a component of the connector switch. The minor switch is used to make a selection between the different stations on a party line.

Two digits are required to operate the connector switch, and an additional digit is provided to operate a minor switch. Hence, the three-digit line station numbers are required in finder-connector systems.

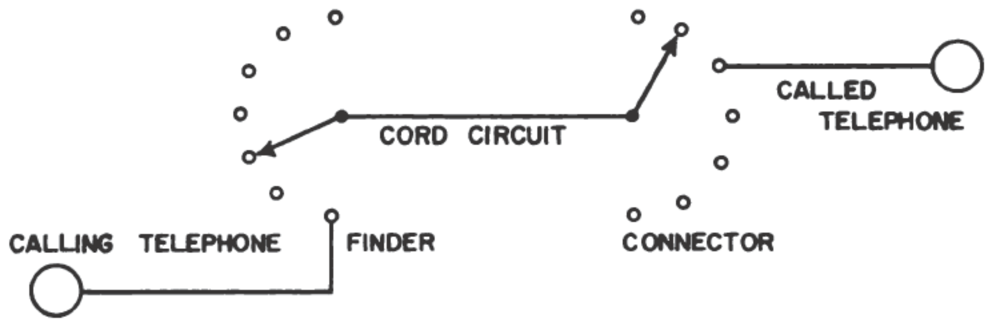


Figure 9—11.—Finder-connector link.

In the basic 100-line finder-connector system (fig. 9–7) each finder switch is permanently connected to a connector switch as illustrated in figure 9–11.

The finder faces backward, ready to find any line that originates a call; whereas, the connector faces forward ready to connect to the dialed line. Such a combination of finder and connector is called a finder-connector link. One finder-connector link is required for each of the conversations that are held simultaneously. These links are analogous to the cord circuits in a manual telephone system.

Selector Switch

The selector switch is used only in systems of 200-line capacity or greater. This switch combines the function of a numerical switch with that of a nonnumerical switch. In other words, it steps its wipers UP under control of a dial impulse, and it rotates its wipers IN automatically on the dialed level, hunting for an idle trunk to the corresponding HUNDRED group of connector switches.

A selector switch is not provided with vertical interrupter springs because the vertical stepping is dial controlled. However, it is equipped with rotary interrupter springs because the rotary stepping is automatic. Cam

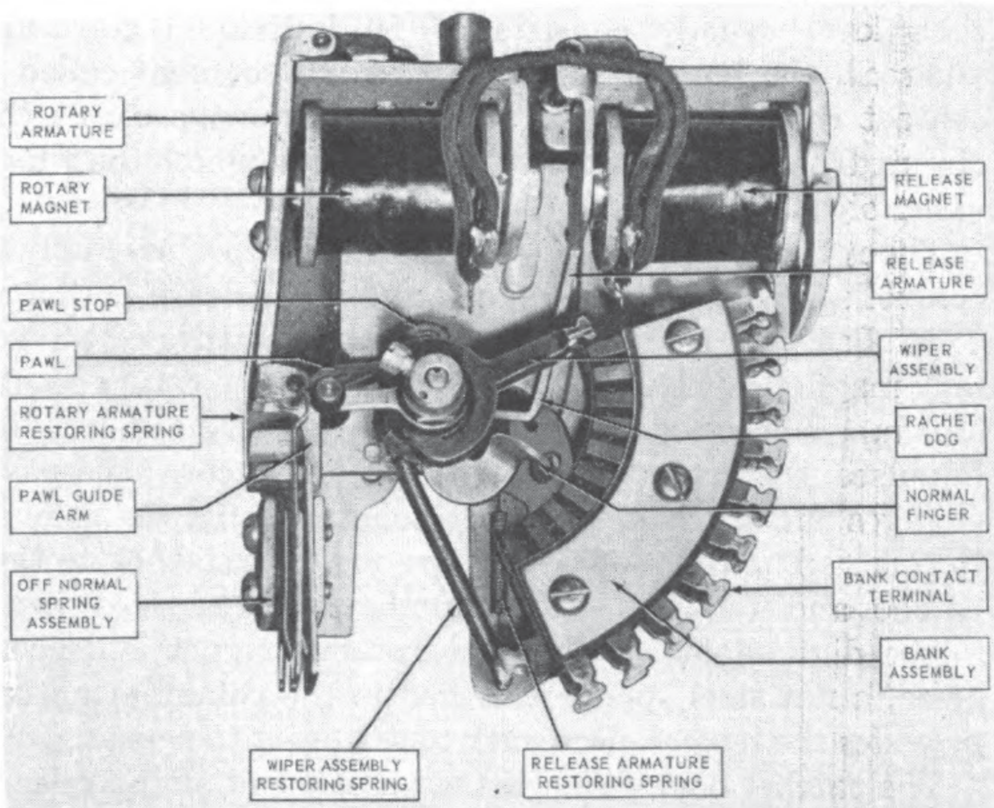


Figure 9—12.—Minor switch.

springs are provided that operate on the eleventh rotary step when all trunks on the dialed level are busy. This switch is usually equipped with five relays.

Minor Switch

The minor switch, as previously mentioned, is mounted as part of the connector switch. It is a one-function auxiliary switch used for making a selection between one or the other of the two parties on a party line. The minor switch has rotary motion only, and consists of a bank assembly, a wiper assembly, and the mechanism necessary to move the wipers (fig. 9–12). The bank assembly has 10 sets of contacts, arranged in an arc similar to one level of a Strowger switch bank, over which the wipers step under control of a dial impulse. Actually, the bank assembly of a minor switch can be one or more levels deep, depending on the circuit requirements. One pair of wiper springs is provided for each level. The upper surface of

each level usually consists of 10 individual contacts; whereas, the bottom surface is a solid segment called a contact common. The pair of wiper springs closes the circuit from the particular top contact, on which the wiper assembly stops, to the contact common.

The rotary stepping movement of the wiper assembly is controlled by a rotary magnet and the release action is controlled by a release magnet. The armature of the rotary magnet carries a pawl that operates the rotary mechanism. When the rotary magnet is energized by dial impulses, the armature is attracted to the core; the pawl engages one of the teeth on a ratchet, causing the ratchet to turn. The pairs of wipers are rigidly attached to this ratchet and step with it. The number of steps corresponds to the digit dialed. When the rotary magnet is deenergized, a flat steel spring attached to the rotary armature provides the tension necessary to restore it to normal.

The ratchet dog, which is the hooked end of the release magnet armature, is controlled by the release armature restoring spring and the magnet. The ratchet dog engages the teeth on the ratchet wheel and retains the wipers on the contacts to which they have been stepped by the rotary mechanism. As the wipers step, the wiper assembly restoring spring (attached to the wiper assembly) increases its tension. This tension restores the wipers to the normal position (one step off the first contact) as soon as the release magnet operates and disengages the ratchet dog from the ratchet.

Minor switches are equipped with a minor-switch-off-normal spring assembly called the MSON spring. These springs are actuated on the first rotary step and usually serve to operate the release circuit of the minor switch, and the release signal of the connector switch with which the minor switch is associated. With respect to this release signal function, the connector release signal will operate to give a warning if the Strowger switch and the minor switch do not restore properly to their normal positions.

QUIZ

1. What is the type of telephone switchboard that is provided with one terminal (jack) for each local line and is limited to the size that permits the operator at the switchboard to reach every line terminal unless local or transfer trunks are provided?
2. What is the type of telephone switchboard that is provided with two or more line terminals connected in multiple to each telephone line and arranged so that the operator at the switchboard can reach at least one jack for each line?
3. Name the three principal components that comprise the switching mechanism in a manual switchboard.
4. (a) Name the three connections provided in the jacks on a manual switchboard. (b) What is the function of each?
5. What is the purpose of the repeating coil or retardation coil contained in each cord circuit?
6. What type of switching mechanism is most extensively used on automatic switchboards aboard naval vessels and what is the principle of operation?
7. Define a relay.
8. Name the four principal components of a telephone relay.
9. Name the three types of telephone relay springs.
10. What action occurs in the make and break springs when a telephone relay is energized?
11. (a) What are the springs on a telephone relay called? (b) What is the maximum number of springs in one assembly? (c) What is the maximum number of springs if two assemblies are required?
12. Name the four basic types of spring assemblies.
13. Name the three general types of telephone relays.
14. What is a slow-to-operate relay and how is this feature accomplished?
15. What is a slow-to-release relay and how is this feature accomplished?
16. Name the two features incorporated in the construction of the a-c telephone relay not found in the d-c relay and the purpose of these features.
17. What is the purpose of the short-lever armature relay?

18. What is the purpose of the double-armature relay?

19. (a) What is a two-step relay? (b) Give an example.

20. What is a twin-contact relay and what is the purpose of this relay?

21. What is a type-Z relay?

22. What is meant by spring gaging?

23. What is meant by spring margining?

24. Name the four different types of switches generally used in the shipboard automatic telephone system.

25. Name the three principal components of the basic Strowger switch.

26. Name the bank assemblies included in (a) the connector switch and (b) in the finder switch.

27. How many sets of double contacts are in the private bank and in the line bank of the 100-line dial telephone system?

28. How are these double sets of contacts arranged in a private or line bank?

29. How many sets of wipers are provided with a private or line bank?

30. (a) How is each individual contact arranged with respect to the other contacts? (b) Where is the terminal located to which is connected one of the line wires or trunk wires of the associated switch?

CHAPTER 10

DIAL TELEPHONE LINE STATION EQUIPMENT

The line station equipment used in the dial telephone system consists of various types of telephones for mounting in both protected and exposed locations. In addition, special extension, or loud-ringing signals are provided for telephones installed in unusually noisy locations.

TYPES OF LINE STATION EQUIPMENT

The types of line station equipment are the (1) type A desk telephone, (2) type B bulkhead telephone, (3) type C watertight bulkhead telephone, (4) type D intercommunicating telephone, and (5) type E compact telephone. The standard telephone handsets used in types A, B, C, and E telephones are identical. Each handset consists of a transmitter and receiver unit mounted together in the same protective shell, as previously described in the training course, *I. C. Electrician 2,* NavPers 10556. Each of the four types is provided with retaining springs to hold the handsets securely in place when they are not in use.

Type A Desk Telephone

The type A desk telephone is installed in staterooms, cabins, offices, and similar stations. It consists of a phenolic case (containing the ringer and other components), a handset, and a connecting cord with a terminal

Figure 10–1.—Type A desk telephone.

block for the line connections (fig. 10–1). All of these parts are inter-connected with each other as indicated on the circuit label pasted inside the telephone.

The handset is provided with a special bracket, on each side of the telephone case, that grips the sloping inner edge of the transmitter and receiver ends of the handset to prevent it from jarring loose from the cradle switch. The left bracket is fixed; whereas, the right bracket is pivoted so that the handset is movable through a short arc.

To remove the handset from the cradle switch, grasp it with the left hand and press on the ball of the locking lever with the left thumb (fig. 10–1). Then lift the receiver end upward, continuing to press on the ball so that the handset and locking lever move simultaneously. As the locking lever clears the handset, the retaining bracket presses against the side plate and inserts a shoulder under the locker lever to prevent it from dropping back, thereby releasing the handset.

To replace the handset in the cradle switch, place the transmitter end in the left retaining bracket and then place the receiver end in the right retaining bracket. As the receiver end drops in place, it strikes an arm on the

retaining bracket and forces the bracket back to its original position. This action allows the locking lever to drop behind the bracket to lock it and the handset securely in place.

The wiring diagram of a type A desk telephone is illustrated in figure 10–2. One-party service (metallic ring) is provided on this telephone by connecting the *L*1 (+) and *L*2 (−) line wires to terminals 1 and 2, respectively, at the cord terminal block located at the end of the telephone cord. The green (GR) ringer wire inside the telephone is connected to the *L*2 line terminal. Proper operation of the ringer is determined by dialing from a

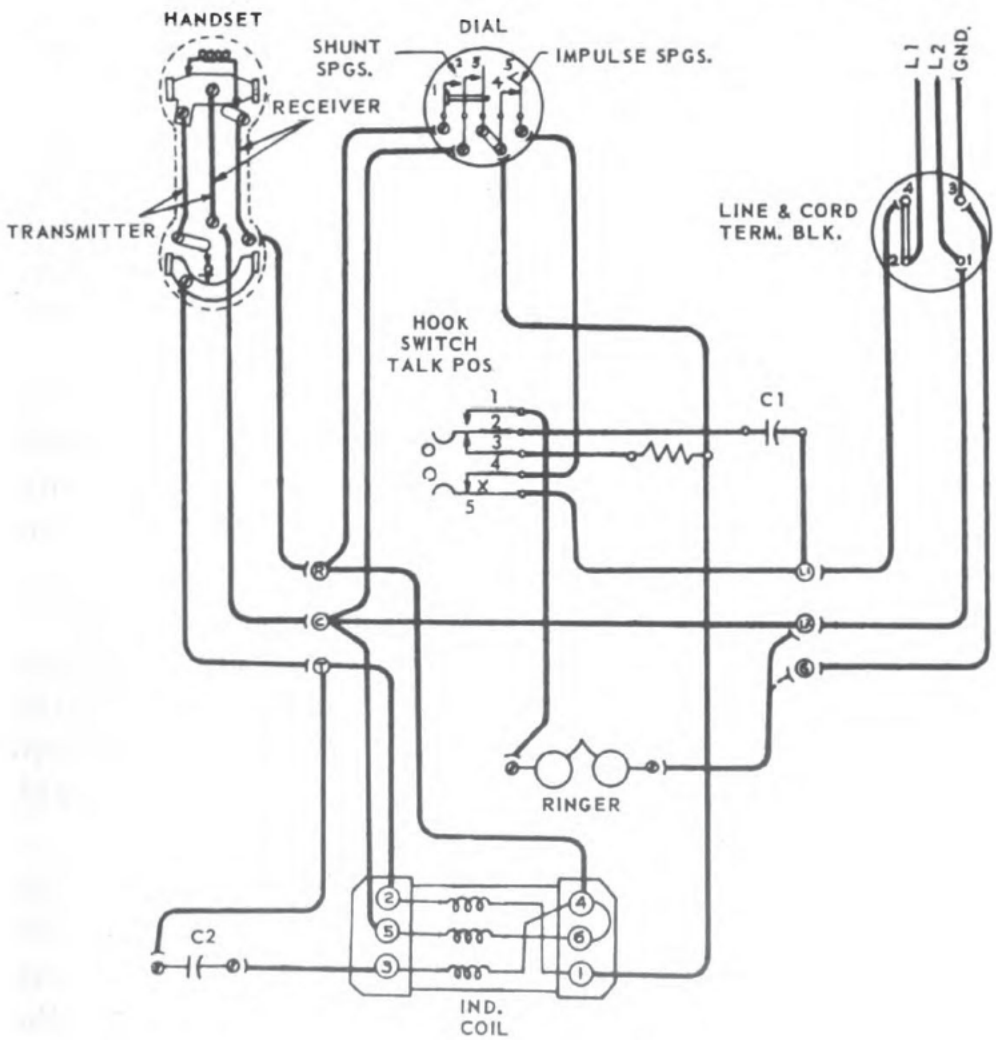


Figure 10—2.—Type A telephone wiring diagram.

nearby telephone the number assigned to the telephone just connected.

Two-party service (ground ring) is provided on this telephone by connecting the $L1$ and $L2$ line wires to terminals 1 and 2, respectively, at the cord terminal block. The common ringing return conductor, *RNGR*, at the switchboard line terminal block is connected to terminal 3 at the cord terminal block. The green (GR) ringer wire inside the telephone is disconnected from terminal $L2$ and connected to terminal G (fig. 10–2). Proper operation of the ringer is determined by dialing from a nearby telephone the number assigned to the telephone just connected. If the bell does not ring, reverse the line wires, $L1$ and $L2$, at the cord terminal block and repeat the test.

The RINGING CIRCUIT is from $L1$ to the line and cord terminal block, to the ringing capacitor, $C1$, through the upper contact of the cradle switch, to the ringer, back to the line cord and terminal block, and to $L2$. The upper contact of the cradle switch will be closed when the handset is resting on the cradle.

The DIALING CIRCUIT is from $L1$ to the line and cord terminal block, through the lower contact of the cradle switch, to the dial impulse springs, and through the right-hand contact of the dial shunt springs, back to the line and cord terminal block, and to $L2$. The right-hand contact of the dial shunt springs is closed when the dial is returning to normal after it is released, thus shunting out the transmitter, receiver, and induction coil. As the dial is returning to normal the impulse springs are opened intermittently by a cam. An impulse is produced each time the impulse springs are opened.

The transmission circuit of a telephone includes the transmitter, the receiver, the induction coil, and the capacitor, $C2$, as illustrated by the schematic diagram in figure 10–3. These components are used in both the transmission and reception of speech.

The main TALKING CIRCUIT is from $L1$ (fig. 10–2) to the line and cord terminal block, through the lower contact of the cradle switch, to the dial impulse springs, through winding 1–2 of the induction coil, to the transmitter, back to the line and cord terminal block, and to $L2$. This circuit is described in detail in the training course, *I. C. Electrician 2*, NavPers 10556.

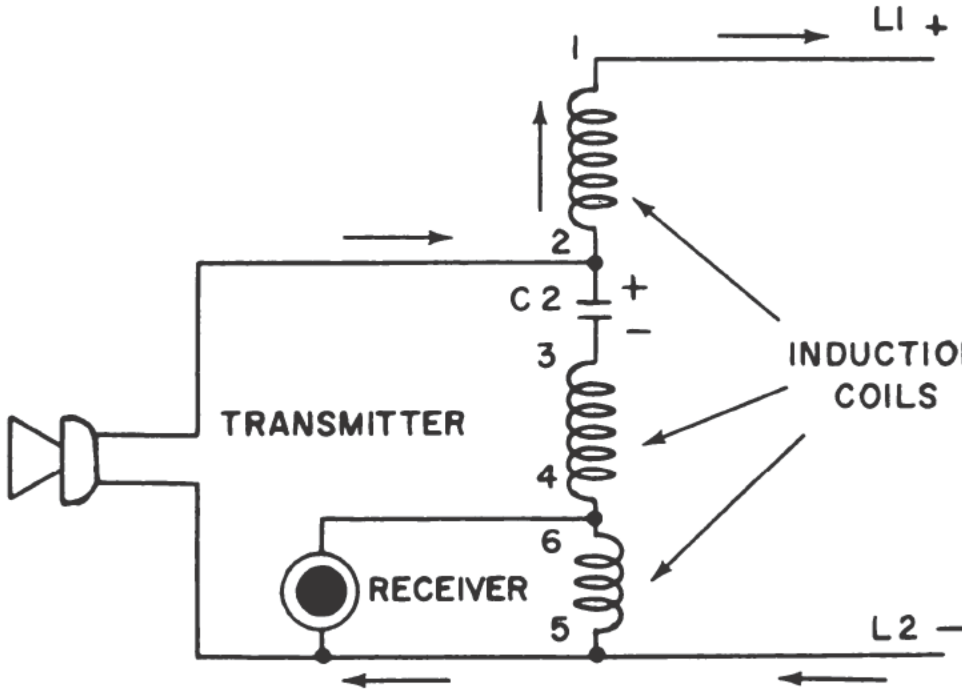


Figure 10—3.—Telephone transmission circuit.

The RECEIVING CIRCUIT is from $L1$ to the line and cord terminal block, through the lower contact of the cradle switch, through the impulse springs, to winding 1–2 of the induction coil, to the transmitter, back to the line and cord terminal block, and to $L2$. The pulsing current through the 1–2 winding of the induction coil generates a-c voltages in the 3–4 winding of the induction coil, which flow in the closed path including the capacitor, $C2$, the transmitter, and the receiver. Winding 5–6 is in shunt with the receiver and has a high impedance that makes its effect negligible on the receiver current.

Type B Bulkhead Telephone

The type B bulkhead telephone is installed in all stations, except those on weather decks and those designated as type A stations. It consists of a special ringer movement and other components that are enclosed in a metal housing designed for bulkhead mounting. The gongs are located on the outside at the top of the housing. The handset and dial are mounted on the front plate (fig. 10–4). This telephone can be provided with a loud-ringing extension signal instead of the standard ringer.

The handset is held in a vertical position by a retaining mechanism in upper and lower receptacles that are recessed in the front plate.

The upper receptacle, which holds the receiver end of the handset, is equipped with a dished blade that is forced outward against the tension of a coil spring inside the telephone. When the receiver end is pressed into this receptacle, it forces the blade inward to operate the cradle switch inside the telephone.

The lower receptacle, which holds the transmitter end of the handset, is equipped with a retaining blade that is forced outward against the tension of a leaf spring. The retaining blade is provided with a positive lock in the form of a sliding bolt. When the transmitter end is pushed downward into this receptacle, spring tension forces the sliding bolt in behind the retaining blade. In this position the blade is locked and the transmitter end is securely held in the receptacle.

To remove the handset, grasp it with the left hand and press the special lever on the front plate with the left thumb to withdraw the locking bolt. Then push the handset upward and the receiver end inward simultaneously until the transmitter end can be lifted clear of the receptacle. As the handset is removed, the retaining blade moves and holds the bolt in the unlocked position.

To replace the handset, place the receiver end in the upper receptacle and press the dished blade inward. Then

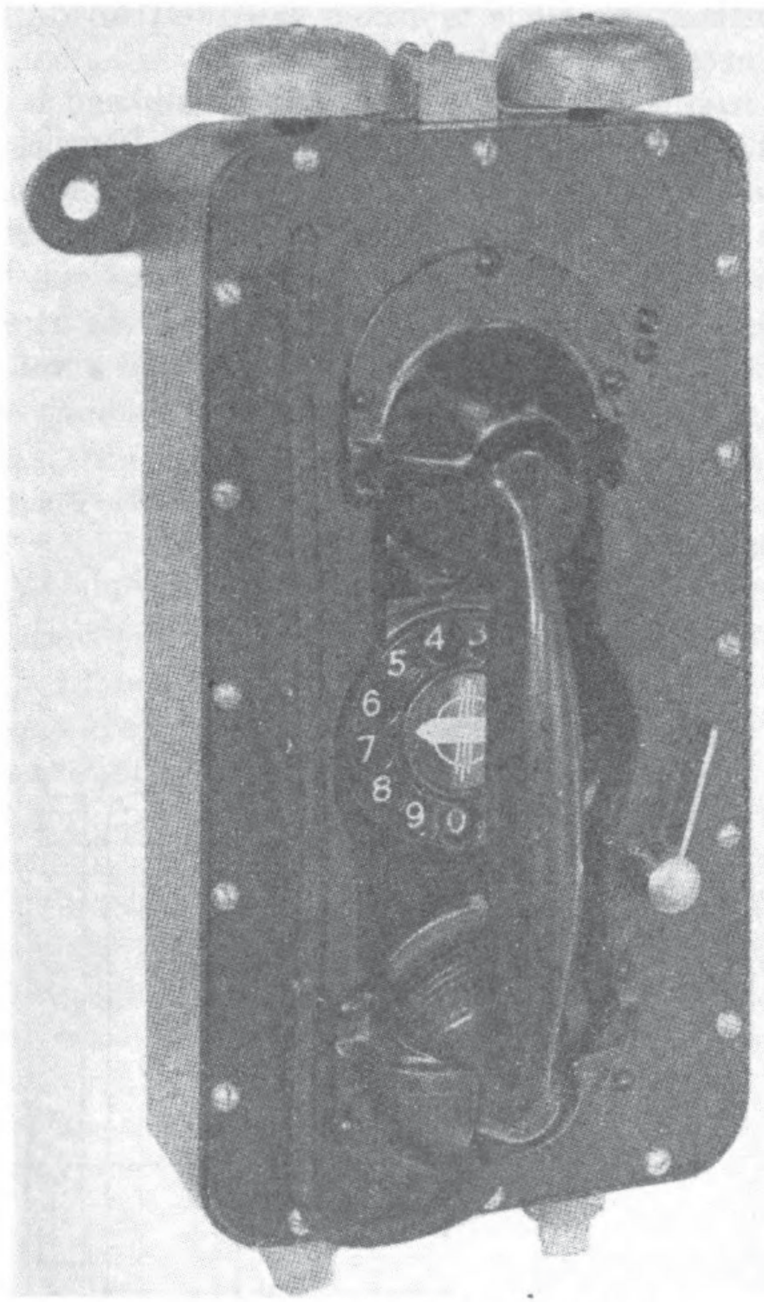


Figure 10—4.—Type B bulkhead telephone.

bring the handset into the vertical position and press downward. When the transmitter end nears the lower end of this receptacle, it presses against a right-angle member on the retaining blade. This action rotates the blade back into the locking position, and spring tension forces the sliding bolt in behind the retaining blade. In

this position the blade is locked and the transmitter end is held securely in the receptacle.

The wiring diagram of the type B bulkhead telephone is illustrated in figure 10–5. The line connections are made at the terminal strip located inside the housing. The circuits are similar to those of the type A telephone. One-party service is provided on this telephone by connecting the *L*1 and *L*2 line wires to terminals *L*1 and *L*2, respectively, at the terminal strip. The green (GR) ringer wire is connected to the *L*2 terminal on the terminal strip. Proper operation of the ringer is determined by dialing from a nearby telephone the number assigned to the telephone just connected.

Two-party service is provided on this telephone by connecting the *L*1 and *L*2 line wires to terminals *L*1 and *L*2,

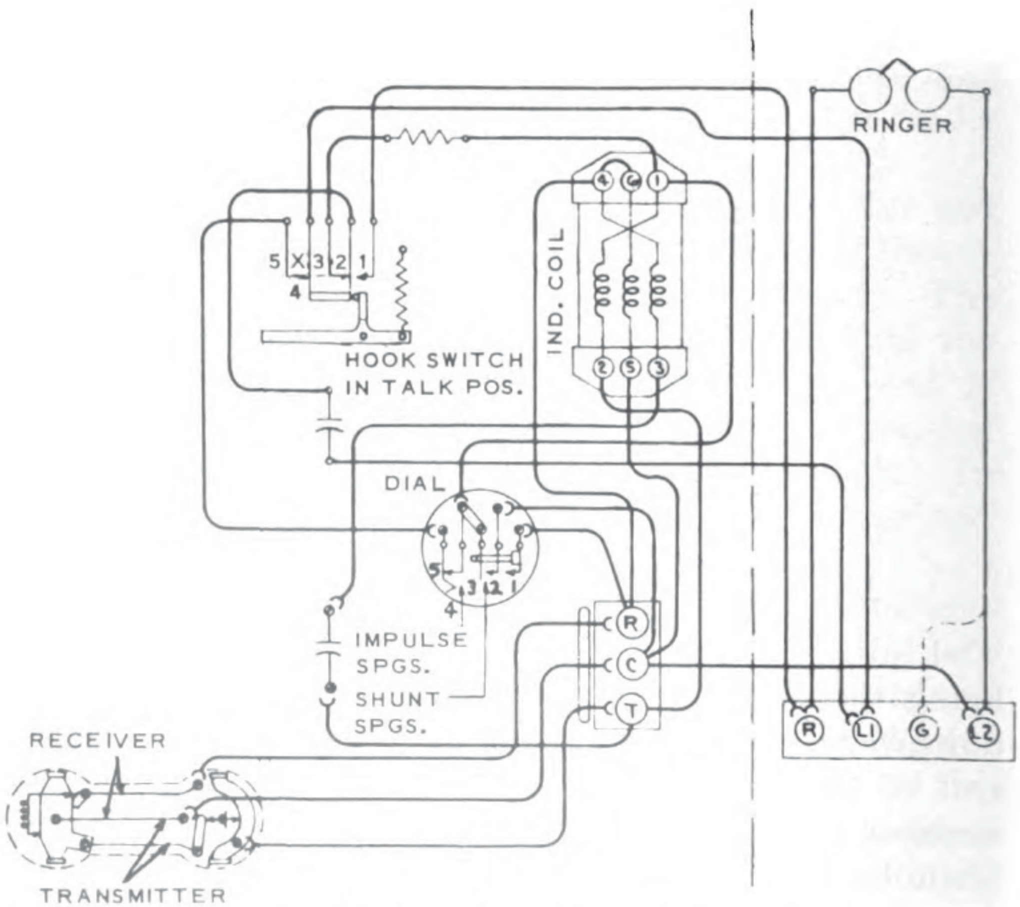


Figure 10—5.—Type B bulkhead telephone wiring diagram.

respectively, at the terminal strip. The common ringing return conductor, *RNGR*, at the switchboard line terminal block is connected to terminal *G* on the terminal strip. The green (GR) ringer wire is disconnected from terminal *L*2 and connected to terminal *G* (fig. 10–5). Proper operation of the ringer is determined by dialing from a nearby telephone the number assigned to the telephone just connected. If the bell does not ring, reverse the line wires, *L*1 and *L*2, at the terminal strip and repeat the test.

EXTENSION SIGNAL.—As previously stated, the extension signal is used with type B bulkhead telephones located in noisy locations or in locations where personnel are usually beyond hearing range of the ordinary telephone ringer.

The extension signal is a motor-operated horn designed for bulkhead mounting. It operates on 120-volt a-c or d-c power instead of the regular ringing current. Hence, it is necessary to interpose a relay, which operates on the regular ringing current between the telephone and the extension signal.

POWER SIGNAL RELAY.—The power signal relay used with extension signals is always associated with a telephone that requires the use of a 120-volt extension signal. It is enclosed in a watertight housing designed for bulkhead mounting and is connected to the ringer leads of the telephone instead of the ringer (fig. 10–6). When a line station equipped with a power signal relay is signaled, the ringing current supplied to the line causes the relay to operate and closes the 120-volt circuit to the extension signal.

All telephones provided with extension signals should be connected for ground ring, irrespective of whether they are used on one- or two-party lines. This arrangement is necessary (during dialing) to avoid the possibility of the inductive discharge of the line relay affecting the power signal relay, and causing intermittent operation.

The line wires, *L*1 and *L*2, are connected to the ter-

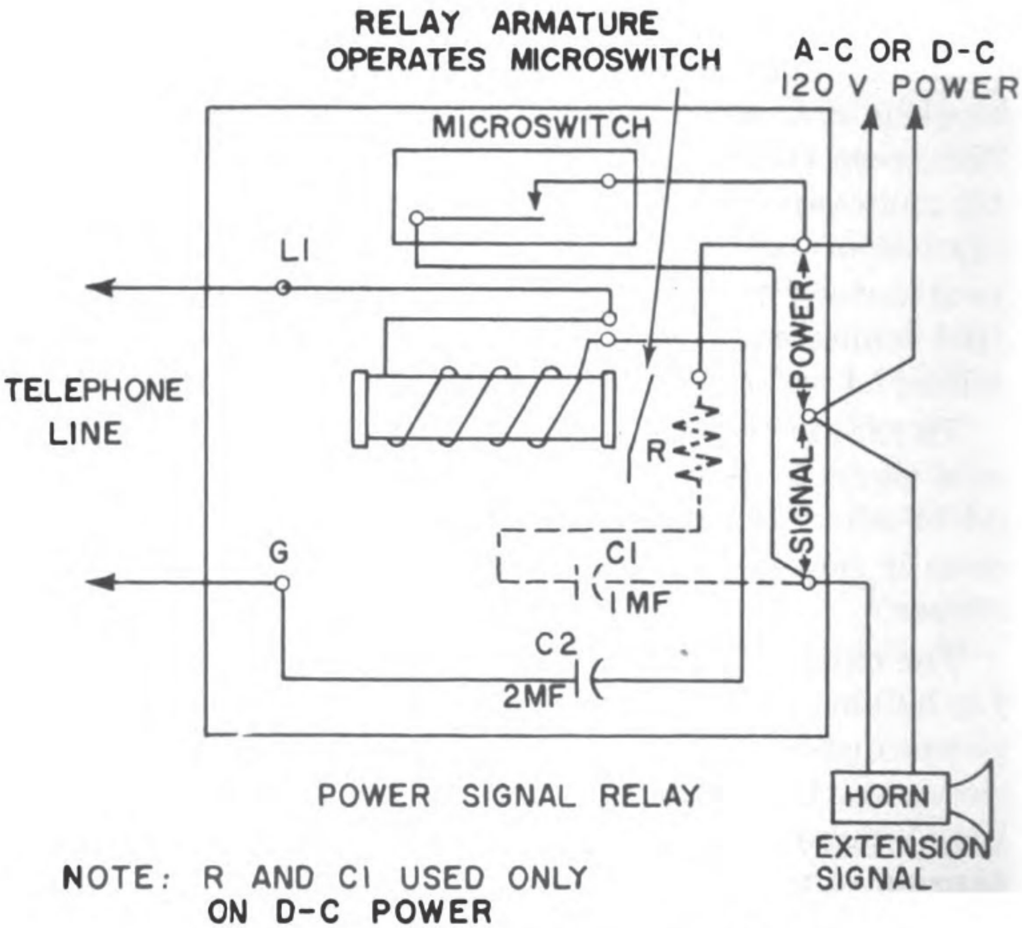


Figure 10—6.—Extension signal with relay.

minals, *L*1 and *L*2 on the terminal strip inside the telephone housing (figure 10–5). The common ringing return conductor, *RNGR*, at the switchboard line terminal block is connected to terminal *G*. The green (GR) ringer wire is disconnected from terminal *L*2 and connected to terminal *G*. The telephone line wires from the power signal relay are connected to terminals *L*1 and *G*. The extension signal is connected to the two terminals designated "signal," and the 120-volt power is connected to the two terminals designated "power," at the power signal relay fig. 10–6. Proper operation of the extension signal is determined by dialing from a nearby telephone the number assigned to the telephone just connected. If the horn does not sound, reverse the *L*1 and *L*2 line wires at the terminal strip inside the telephone and repeat the test.

Type C Watertight Bulkhead Telephone

The type C watertight bulkhead telephone is installed in stations on weather decks and in other stations exposed to moisture. It comprises the same working parts as the type B bulkhead telephone but is enclosed within a knurled water-tight housing provided with a hinged door and a handle located on the right side of the housing (fig. 10–7).

To use the telephone, unscrew the knurled handle, open the door, and remove the handset, as previously described for the type B telephone. To secure the telephone, replace the handset, close the door, and tighten the handle. The latch automatically engages the door when the handle is secured.

The wiring diagram and the connections of the type C telephone for one- and two-party services are similar to those previously described for the type B telephone.

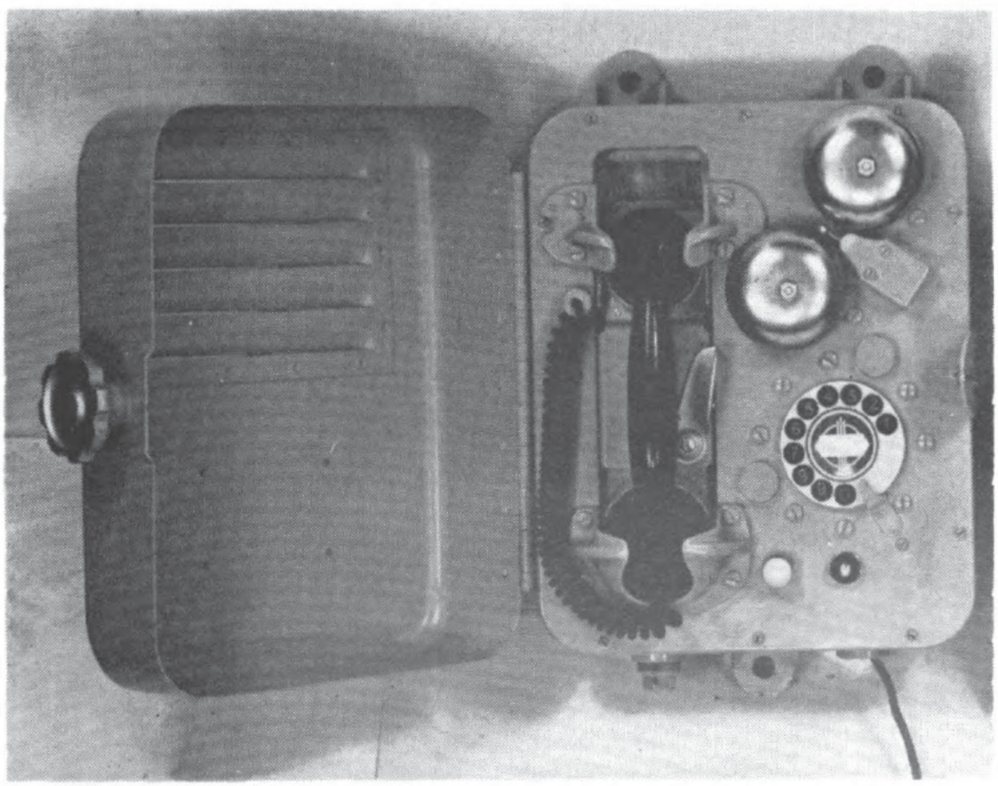


Figure 10—7.—Type C watertight bulkhead telephone.

Type D Intercommunicating Telephone

The type D intercommunicating telephone is installed only in flagships. It is designed to provide a combined dial telephone and intercommunicating station. This telephone operates as an intercommunicating system composed of 11 stations or less, which can be entirely independent of the ship's dial telephone system. Any 1 of the 11 stations in this intercommunicating system can be connected to the dial telephone system by connecting it to the automatic switchboard. Calling parties at stations in the intercommunicating system must dial the desired stations in the dial telephone system and vice versa.

The intercommunicating system provides loudspeaker

Figure 10—8.—Type D intercommunicating telephone.

communicating service and dial telephone service. Thus, it is possible to talk on 1 of 10 other line stations that use either of these services by operating the proper control on the type D desk unit.

The type D intercommunicating telephone consists of a desk unit interconnected by a cable to a bulkhead unit (fig. 10–8). The desk unit includes the station selector keys with release key, the station call lamps, the loudspeaker, the telephone handset, the dial, and the ringer. Also included are the necessary operating controls, such as the power ON-OFF switch with indicator lamp, the handset transfer switch, the talk switch, and the volume control switch. The bulkhead unit contains the power supply, the amplifier, the jack unit, and the connecting jacks.

The type D intercommunicating telephone system is designed to establish connections between a maximum of three stations at one time without appreciable loss in volume of reproduction. However, if a connection is established between more than three stations simultaneously the volume will be reduced with the addition of each station.

The power supply and the amplifier contained in the bulkhead unit (fig. 10–9) are required for the operation of the intercommunicating system. When the power switch, *SW*1 (not shown) is in the *ON* position, the primary of the power transformer, *T*1, is energized from the ship's single-phase 120-volt power. The secondary of *T*1 provides the various voltages necessary for the rectifier and the amplifier, and for signaling.

To call a station, the selector key (*K*1 through *K*10), having the designation of the station to be called, is depressed at the calling station. For example, if station 3 calls station 1, selector key *K*1 is depressed at station 3. If station 1 is busy, the associated call lamp, *L*1, at station 3 flashes. If station 1 is free, *L*3 lights steadily. When the call is answered by station 1, the associated call lamp, *L*1, at station 3 begins flashing. A call lamp,

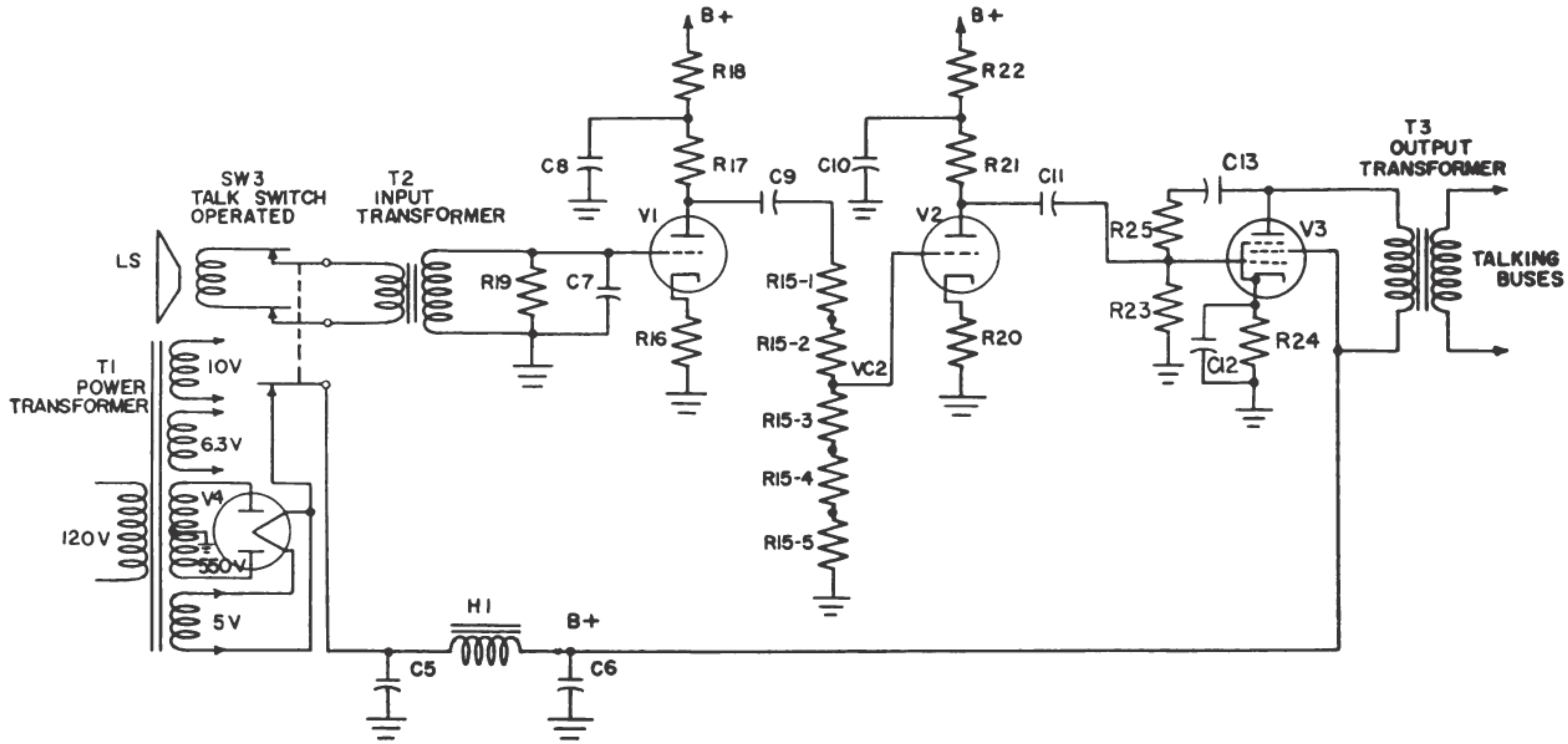


Figure 10—9.—Type D telephone power supply and amplifier talking circuits.

which has the designation of the calling station, lights steadily at each called station, irrespective of whether the station is busy or free.

The flasher motor, $M1$ (not shown), is energized from the 10-volt secondary of the power transformer located in the bulkhead unit. When selector key $K1$ is depressed the flashing signal circuit (from station 1 to call lamp $L1$ of station 3) flashes if the called station is busy. After being operated, the locking-type selector keys must be restored by depressing the release key.

To answer a call from another station, the selector key corresponding to the lighted call lamp is depressed at the called station. For example, station 1 answers the call from station 3 when selector key $K3$ is depressed. The associated call lamp, $L1$, at station 3 and the associated call lamp, L 3,at station 1 start flashing when the call is answered and continue to flash until the release key is depressed to break the connection.

All stations in the intercommunicating system can receive when the selector keys are at normal. Hence, the party at the calling station can start talking immediately after operating the selector key of the called station, or can wait for the flashing signal to indicate acknowledgement by the called station.

The desk unit provided at each station can be used as a microphone or as a loudspeaker by operating the talk switch, $SW3$, each time the unit is used for transmission. When the talk switch is operated, the desk unit functions as a microphone (fig. 10–9). The full-wave rectifier, $V4$ supplies B+ voltage to the plates of the first- and second-stage amplifier tubes, $V1$ and $V2$, and to the screen grid and plate of the third-stage amplifier tube, $V3$, through the filter choke, $H1$. The voice currents induced in the voice coil of the loudspeaker are fed through the input transformer, T2, to the grid of $V1$. The output of $V1$ is fed (through the coupling capacitor, $C9$, and the gain control potentiometer, $VC2$) to the grid of $V2$. The

signal is further amplified in the output stage tube, *V*3, and is fed to the output transformer, *T*3. Similar currents are induced in the secondary of *T*3 and are transmitted over the talking buses to each station that is connected to these buses.

When the talk switch, *SW*3, is released to the normal position the amplifier is deenergized, and the desk unit functions as a loudspeaker. The amplified voice currents from any other station connected with the talking buses are induced in the voice coil of the loudspeaker to reproduce sound. The volume of the loudspeaker can be varied somewhat by adjusting the volume control switch, *VC*1 (not shown) in the desk set.

The handset of the desk unit provided at each station can be used for transmission over the intercommunicating system by operating the handset transfer switch, *SW*4 (not shown) to the I. C. SYSTEM position and removing the handset from the cradle switch. This action disconnects the loudspeaker and transfers the handset to the intercommunicating system.

When the party at a station talks into the transmitter of the handset, the voice currents are amplified at that station and transmitted to the talking buses to other stations on the connection. On the other hand, when a party at one of the other stations on this connection talks, the amplified voice currents from that station flow through the receiver circuit of the handset to reproduce sound.

When the conversation is terminated, the connection is released by pressing the (red) release button at each station on the connection to release the associated operated selector key or keys. This release button restores to normal when released because it is not of the locking type. If desired, one or more connections can be retained while the remaining connections are released by holding down the selector keys of the stations (to be retained) while depressing the release button. The telephone is prepared for receiving calls on the dial telephone system by re-

placing the handset on the cradle switch and operating the handset transfer switch to the DIAL TELEPHONE SYSTEM position.

Type E Compact Telephone

The type E compact telephone is installed in stations similar to those of the type A telephone. It can be used as an extension telephone, requiring two wires to its associated main line telephone. When used as a main line telephone, a separate ringer box containing a ringer and a terminal strip is required.

The telephone consists of a base on which are mounted the induction coil, the capacitors, the resistor, the hook-

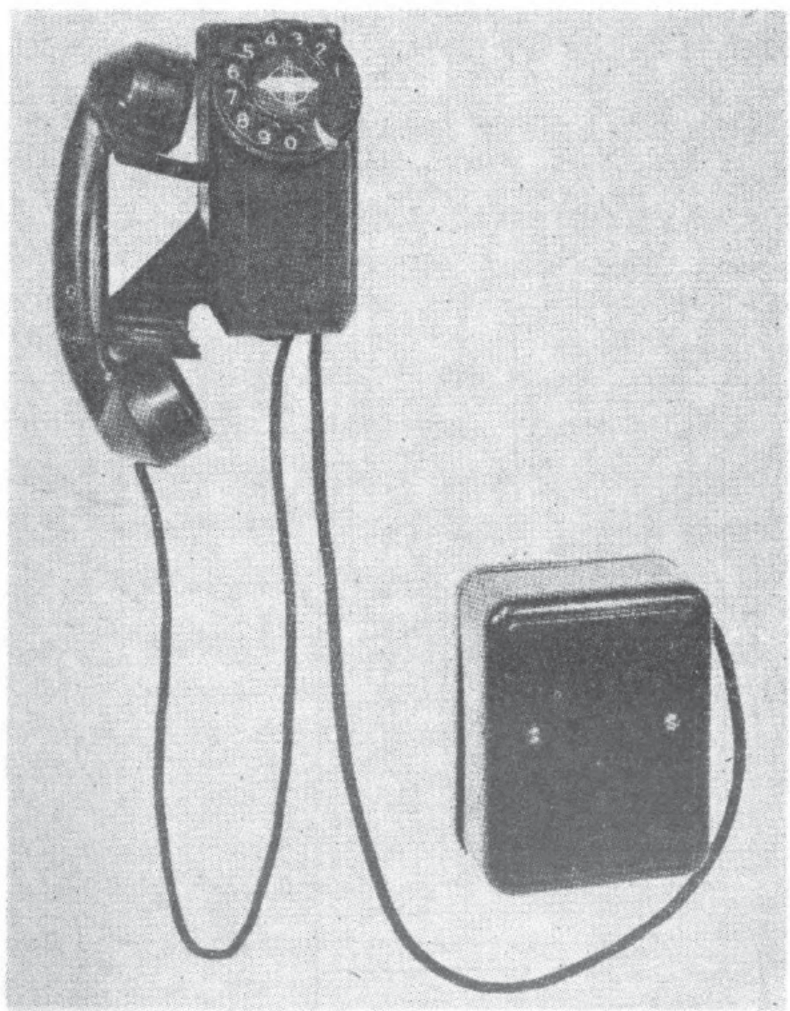


Figure 10—10.—Type E compact telephone.

switch, and the terminal strip. The dial forms part of the cover, which is securely fastened to the base by a single screw. A standard handset is included to complete the unit (fig. 10–10). This unit can be mounted on a stanchion, a bulkhead, or on the side or end of a desk.

The wiring diagram of the type E compact telephone is illustrated in figure 10–11. One-party service is provided on this telephone (when used as a main line unit) by connecting the three wires from terminals 1, 2, and 3 of the terminal strip in the telephone to terminals *L*1, *L*2 and *R*3, respectively, of the terminal strip in the ringer box. The green (GR) ringer wire is connected to the *L*2 terminal in the ringer box. Proper operation of the ringer is determined by dialing from a nearby telephone the number assigned to the telephone just connected.

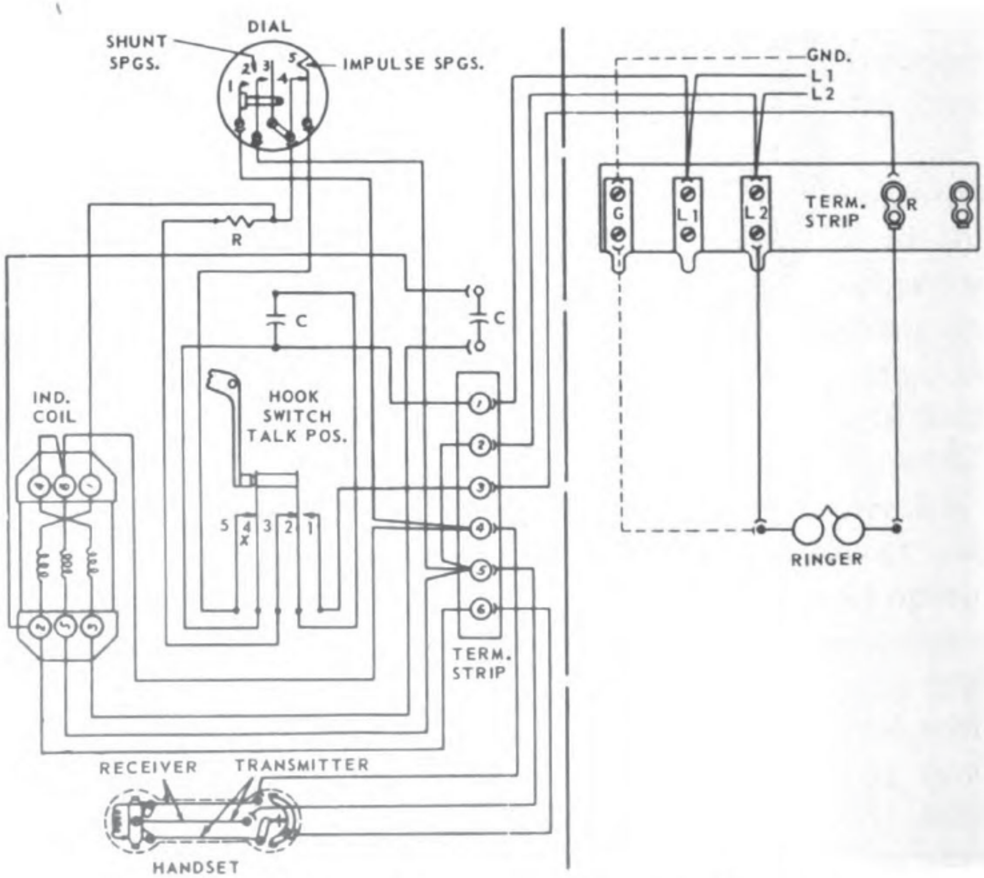


Figure 10—11.—Type E compact telephone wiring diagram.

Two-party service is provided on this telephone by connecting the three wires from terminals 1, 2, and 3 of the terminal strip in the telephone to terminals *L*1, *L*2, and *R*, respectively, of the terminal strip in the ringer box. The common ringing return conductor (from the switchboard) is connected to terminal *G*. The green (GR) ringer wire is disconnected from terminal *L*2 and connected to terminal *G* (fig. 10–11). Proper operation of the ringer is determined by dialing from a nearby telephone the number assigned to the telephone just connected. If the bell does not ring, reverse the line wires, *L*1 and *L*2, at the terminal strip and repeat the test.

TROUBLES

Noisy Cord

A noise in the receiver is caused by broken conductors in the telephone cord. This trouble can be detected by rolling the cord back and forth between the hands while listening for a clicking or crackling noise in the receiver. Defective cords must be replaced.

Noisy Connections

Noisy connections are caused by partial shorts or grounds on the line, worn handset or desk set cords, noisy transmitters, and loose connections in the telephone.

Clicks In Receiver While Dialing

Clicks in the receiver while dialing are probably caused by failure of the shunt springs to make contact when turning the dial. If this condition is not corrected after cleaning the contacts, look for a broken shunt spring connection.

Calling And Answering Difficulties

CALLED STATION DOES NOT RING.—If the bell at a called station does not ring, the fault can be caused by an open ringer coil or capacitor, an improper adjustment of the

ringer, or reversed or loose connections at the ringer terninals. Also, the bell will not ring properly if the gongs have become loose or if the position of the gongs has shifted with respect to the clapper.

CANNOT ANSWER.—If a party at a called telephone is signaled but cannot be heard, the fault can be caused by a shorted transmitter or a shorted contact of the dial shunt springs. Also, if the monophone springs fail to operate, the ring will not be cut off when the handset is removed at the called station.

CANNOT HEAR WELL.—If a telephone has poor reception, the trouble may be caused by improper contact of the contact springs in the receiver housing, a loose receiver cap, a worn receiver cord, or loose connections inside the telephone.

CANNOT BE HEARD WELL.—If a telephone has defective voice transmission, the fault is probably in the transmitter unit. To loosen the carbon granules, hold the handset in a horizontal position and shake it, using a circular motion. If the carbon granules are not loosened by this method, strike the transmitter end of the handset sharply with the palm of the hand. Also, check the contact springs in the transmitter for a tight, clean connection to the unit.

CANNOT CALL.—If a call cannot be made from a telephone, first determine if the line relay operates when the handset is removed at the calling station. If the line relay does not operate, short circuit the line terminals at the switchboard. If the line relay now operates, check for an open line between the switchboard and calling telephone.

REPAIRS

In general, when it is necessary to work on a telephone it should be taken out of service by disconnecting the *L*1 and *L*2 line wires. The line wires can be disconnected in the type A telephone at the cord terminal

block located at the end of the desk set cord, and in the types, B, C, and E telephones at the terminal strip inside the housing. This procedure prevents the unnecessary operation of the automatic switches that seize and hold busy a conversation link at the switchboard. To prevent reconnecting line wires in reverse, they should be marked when disconnected.

Access To Interior Of Telephones

Access to the interior of a type A telephone is gained by removing the handset from the cradle switch and turning the telephone over lengthwise (with the bottom plate up) and resting it on the face opposite the dial mounting face. The two base mounting screws located at the extreme opposite ends of the bottom plate should be loosened. However do not loosen any screws located in the middle portion of the bottom plate. The bottom plate is removed by turning it over lengthwise (with the ringer on top).

Access to the interior of a type B and a type C telephone is gained by removing the 16 screws located around the outer edges of the front plate. The front plate, which is provided with a special hinge inside the housing, can now swing out and back. The induction coil and the capacitors are mounted directly on the rear of the front plate. Connection to the terminal strip is through entrance holes in the bottom of this housing.

Access to the interior of a type D telephone desk unit is gained by removing the handset, the cord clamp, and the machine screws that fasten the front panel to the housing. Remove the housing by sliding it from the front panel and base.

Access to the interior of the type D bulkhead unit is gained by removing the machine screws that hold the jack unit located in the lower portion of the front panel and withdrawing the jack-connected unit. Then remove the machine screws that fasten the front panel to the housing and withdraw the entire unit.

Access to the interior of a type E telephone is gained by loosening the single captive screw at the bottom of the telephone and sliding the cover from the base plate.

Removing The Dial Card

The dial escutcheon card is removed by inserting the special dial tool (obtained from the spare parts box) under the escutcheon ring opposite the digit "5" finger hole. Press the tool down against the locking lever underneath the card and move the tool counterclockwise to the digit "6" finger hole. This action unlocks the card assembly. Lift the escutcheon ring at the digit "6" finger hole with the tip of the tool and withdraw the card assembly. The escutcheon ring, the celluloid cover, the dial card, and the dial card clamping plate will release as one assembly. The components can be released by turning the assembly clamping plate in a counterclockwise direction. Notice the relative position of the parts as they are removed so that they can be easily reassembled.

The components of the card assembly are reassembled by placing the celluloid cover and then the dial card into the escutcheon ring. Place the dial card clamping plate over the dial card and turn the clamping plate in a clockwise direction to engage the tongue, thereby locking the assembly. Mount the card assembly on the dial, with the locking lever on the finger plate pointed midway between digits "6" and "7". Insert the small lug on the escutcheon ring into the slot located above the finger stop and press the assembly down into the finger plate. Hold the assembly in place and insert the dial tool under the escutcheon ring opposite the digit "7" finger hole. Press the tool down against the locking lever underneath the card and move the tool in a clockwise direction to the digit "6" finger hole, thereby locking the card in place. Remove the tool.

Replacing The Dial

To replace the dial of any type of telephone, expose the interior, as previously described, and disconnect the four

conductors at the rear of the dial. Remove the three screws and lockwashers that hold the dial in place and lift out the dial. Mount the new dial and replace the lockwashers and screws. Connect the four conductors to the dial in accordance with the circuit label inside the telephone. Dials are properly adjusted and lubricated before shipment and should operate for long periods of time without attention. However, if minor adjustments are required the proper procedures are listed in the instruction book.

Replacing The Cords

A handset or cord on a telephone can be readily replaced because cords are carried (already made up) in the spare parts box. When replacing a handset or cord, refer to the circuit label inside the telephone or make a wiring sketch so that the cord can be connected properly. All wires are color coded, and the connections are made by screw-type terminals. Always anchor the tie cord securely, using sufficient slack in the conductor wires so that no strain is placed on the wires.

Replacing the Transmitter and Receiver Units

The transmitter and receiver are both of the capsule type and thus are completely enclosed self-contained units. These units cannot be opened without damage. In the event of trouble the entire unit must be replaced.

The transmitter unit is held in place in the mounting cup by two retaining spring clips and is secured by the mouthpiece. Connections to the electrodes are through springs. To remove the transmitter unit, hold the handset in a horizontal position (facing up) and unscrew the mouthpiece. If the hand slips, wrap a piece of friction tape around the mouthpiece to provide the necessary friction. Lift the transmitter unit out of the housing, with the fingers engaging the outer edge of the unit between the two retaining spring clips.

To replace the transmitter unit, hold the handset in a

horizontal position, as previously explained. Insert the outer edge of the unit against the movable retaining spring clip (located in the cup) and snap into place, pressing only on the outer edge of the transmitter. Then screw on the mouthpiece.

The receiver unit is held securely in place by the ear cap. Connections to the electrodes are through springs. To remove the receiver unit, hold the handset in a horizontal position (ear cap facing up) and unscrew the ear cap. Place the hand over the receiver housing and turn the handset over. The receiver unit will drop out and into the hand.

To replace the receiver unit, hold the handset in a horizontal position, as previously explained. Place the receiver in the cup and screw on the ear cap.

The receiver unit cannot be inserted into the transmitter mounting cup because of a stop screw in the transmitter cup. This stop screw allows the transmitter unit to be inserted but blocks the receiver unit.

QUIZ

1. Name the five types of line station equipment.
2. What type of service is provided when a telephone instrument is connected for (a) metallic ring and (b) ground ring?
3. Name the four principal circuits in the standard telephone instrument.

REFERRING TO FIGURE 10–2 FOR QUESTIONS 4 THROUGH 9:

4. What is the ringing circuit in figure 10–2?
5. What is the dialing circuit?
6. What is the purpose of the dial shunt springs?
7. What is the purpose of the impulse springs?
8. What is the main talking circuit?
9. What is the receiving circuit?
10. What is an extension signal?
11. Can an extension signal be used with a type B bulkhead telephone?

12. What type of power is required to operate an extension signal?
13. What is the action of the power signal relay when an extension signal is used with the type B telephone?
14. Why must telephones provided with extension signals always be connected for ground ring; irrespective of whether they are used on one-party or two-party lines?
15. What are the dual functions of the type D telephone?
16. How many stations can be connected together simultaneously in the type D telephone system without appreciable loss in volume of reproduction?
17. Name the two principal units of the type D telephone.
18. How can the desk unit at each station in a type D intercommunicating system be used as a microphone or as a loudspeaker?
19. How does the type D desk unit function when the talk switch is operated?
20. How does the type D desk unit function when the talk switch is released?
21. How can the handset of the type D desk unit be used for transmission over the intercommunicating system?
22. Where are the voice currents amplified when the handset is used for talking over the intercommunicating system?
23. How is the type D telephone prepared to receive calls on the dial telephone system?
24. Name the two uses of the type E compact telephone.
25. How can a defective telephone cord be determined?
26. What is the probable cause of clicks in the receiver while dialing?
27. Name five probable faults if the bell at a called station does not ring.
28. Name three probable faults if a party at a called telephone is signaled but cannot be heard.
29. Name four probable faults if a telephone has poor reception.
30. Name two probable faults if a telephone has defective voice transmission.
31. Name a probable fault if a call cannot be made from a telephone.
32. Why should a telephone be disconnected from service when making repairs to the instrument?

CHAPTER 11

DIAL TELEPHONE AUTOMATIC SWITCHBOARD

THE 100-LINE DIAL TELEPHONE SYSTEM

The automatic switchboard of the 100-line dial telephone system is equipped with sufficient switching equipment to accommodate 25 simultaneous conversations (talking circuits). All of the automatic switching equipment is operated on direct current at 48 volts supplied by a battery and motor-generator set. The power equipment is described in another chapter.

Services

This system includes (1) local, (2) outgoing, (3) incoming, (4) executive priority and (5) hunt-the-not-busy-line services.

The LOCAL SERVICE provides station-to-station calls within the ship with provision for both individual and two-party lines.

The OUTGOING SERVICE provides ship-to-shore calls, when the ship is in port, to a manual or automatic shoreline exchange through an attendant's cabinet.

The INCOMING SERVICE provides shore-to-ship calls, when the ship is in port, from a manual or automatic shoreline exchange through an attendant's cabinet.

The EXECUTIVE PRIORITY SERVICE is provided for executive telephones so that these telephones can establish a connection with any other telephone irrespective of whether or not the called telephone is busy.

An outgoing call from an executive telephone is made by dialing the directory number. If the called telephone is in use, the busy tone is not returned to the calling station, but a connection is established that enables the calling party to listen in on the line, to talk with either party, or to retire from the connection.

An incoming call to an executive telephone is made by establishing the connection in the regular manner.

The HUNT-THE-NOT-BUSY-LINE SERVICE (trunk hunting, or group hunting) provides automatic selection of lines for a particular group of lines. When the number of incoming calls to a particular station cannot be handled by one line, the station is assigned a group of two or more telephones (multiple-line group). It is necessary to list only the first number in the group in the directory.

The connector switches are arranged so that when a calling station dials a multiple-line group number, the switch wipers step up to the line of the called station in the regular manner. If the first line of a multiple-line group is busy, the switch automatically steps its wipers IN toward the right until an idle line is found, or until the last set of contacts in the group is reached. If all lines in the group test busy, a busy signal is transmitted to the calling telephone. All of the numbers ending in "0" (zero) appear as the last set of terminals at the right-hand side of the bank, as described in the following paragraphs, and cannot be used as the listed number of a multiple-line group because hunting an idle line proceeds from left to right and cannot continue beyond the right-hand extremity for any given level.

Station Numbering

As previously stated, all telephones in the dial telephone system aboard ship are assigned three-digit numbers. The first digit dialed energizes a minor switch (mounted on the connector switch) that determines the side of the line that is supplied ringing current. The

second and third digits dialed cause the connector switch to step to the desired line. The second and third digits always correspond to the line number. The line numbers available for assignment in the 100-line dial telephone system (expressed in groups) are 11–10, 21–20, 31–30, 41–40, 51–50, 61–60, 71–70, 81–80, 91–90, and 01–00. Each expression contains 10 numbers. For example, the line numbers included in the 11–10 group are lines, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 10. This method of numbering is necessary because number 11 is normally one step UP and one step IN on the connector switch bank; whereas, line number 10 is one step UP and 10 steps IN. This method of numbering applies to all of the line number groups in the system.

If the first digit dialed is 1, 2, 3, 4, 5, 6, 7, 8, or 0, ringing current will be supplied over the positive side of the line and ground after the connector has connected to the line and found it free to receive the call. Conversely, if the first digit dialed is 9, ringing current will be supplied over the negative and positive sides of the line.

When two telephones are connected to the same line, the ringers must be connected between the proper side of the line and the common ringing return conductor, according to the assigned number. For example, if line number 23 is used for two-party service, the ringer of one telephone is connected to the positive side of the line and ground, and the telephone number can be 123, 223, 323, 423, 523, 623, 723, 823, or 023; whereas, the ringer of the other telephone is connected to the negative side of the line and ground, and the telephone number will be 923.

When only one telephone is connected to a line, the ringer can be either bridged across the line or wired to one side of the line and ground. If the ringer is bridged across the line, any three-digit number can be assigned provided that the last two digits correspond to the line number. However, if the ringer is connected to one side of the line and ground, the first digit assigned must be in

accordance with the foregoing method used for the two-party line. The ringers of all telephones that are provided with extension signals must be connected in accordance with the foregoing method described for the one-party line.

One line circuit is assigned permanently for the test line (circuit number 29 in this system). Hence, the corresponding line is not available for any other service. Each of the trunks (circuit numbers 37, 38, 39 and 30 in this system) from the attendant's cabinet to the switchboard utilizes a regular line circuit. These line circuits can be used for local service when they are not being used for shoreline service. A shoreline control switch is located on the lamp and key panel to cut the attendant's cabinet in and out of service. When the ship is not in port, the four line circuits wired for the attendant's cabinet can be used for local service by operating the shoreline control switch to the OFF position. The remaining 95 lines are available for other assignments.

The automatic switchboard is the switching center of the dial telephone system. The switchboard equipment includes the switching mechanisms and the ringing machines along with the associated control circuits, line disconnect keys, alarm signals, and testing equipment. The switching mechanisms, control circuits, line disconnect keys, a portion of the testing equipment, and most of the supervisory alarm signals are mounted on the automatic switchboard. The ringing machines and the common alarm signals are usually mounted externally.

The automatic switchboard comprises a FINDER BOARD and a CONNECTOR BOARD, each enclosed in a steel cabinet. An iron frame work within each cabinet supports the telephone switching equipment that is mounted (in rows) on both sides of the frame. The cabinets are equipped with front and rear hinged doors for access to the switchboard interior.

FINDER BOARD

The equipment mounted on the front of the finder board (fig. 11–1) consists of the supervisory control and alarm relays; lamp and key panel; line relays, distributor relays, line-transfer relays, and all finders-busy relays; fuse panel; line disconnect key panel; and terminal blocks as required. The supervisory control and alarm relays, the lamp and key panel, and line disconnect key panel are

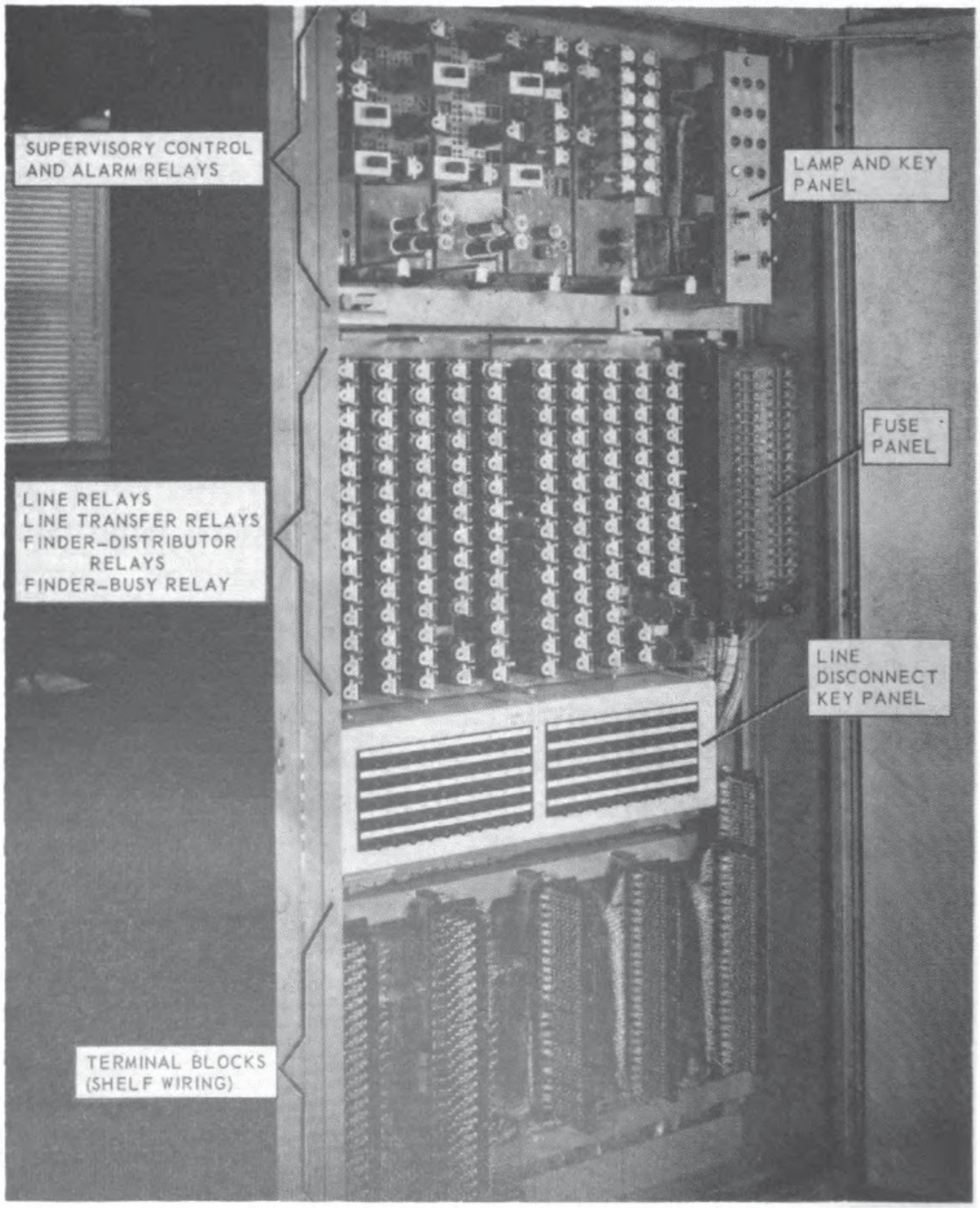


Figure 11—1.—Finder board (front).

described with the alarm and testing equipment in a separate chapter.

The equipment mounted on the rear of the finder board (fig. 11–2) consists of the groups A and B finder switches; the groups A and B finder control switches; a finder test key; a hand test telephone; and a patching cord that is used in connection with the test set mounted on the connector board. The hand test telephone and patching cord are not shown.

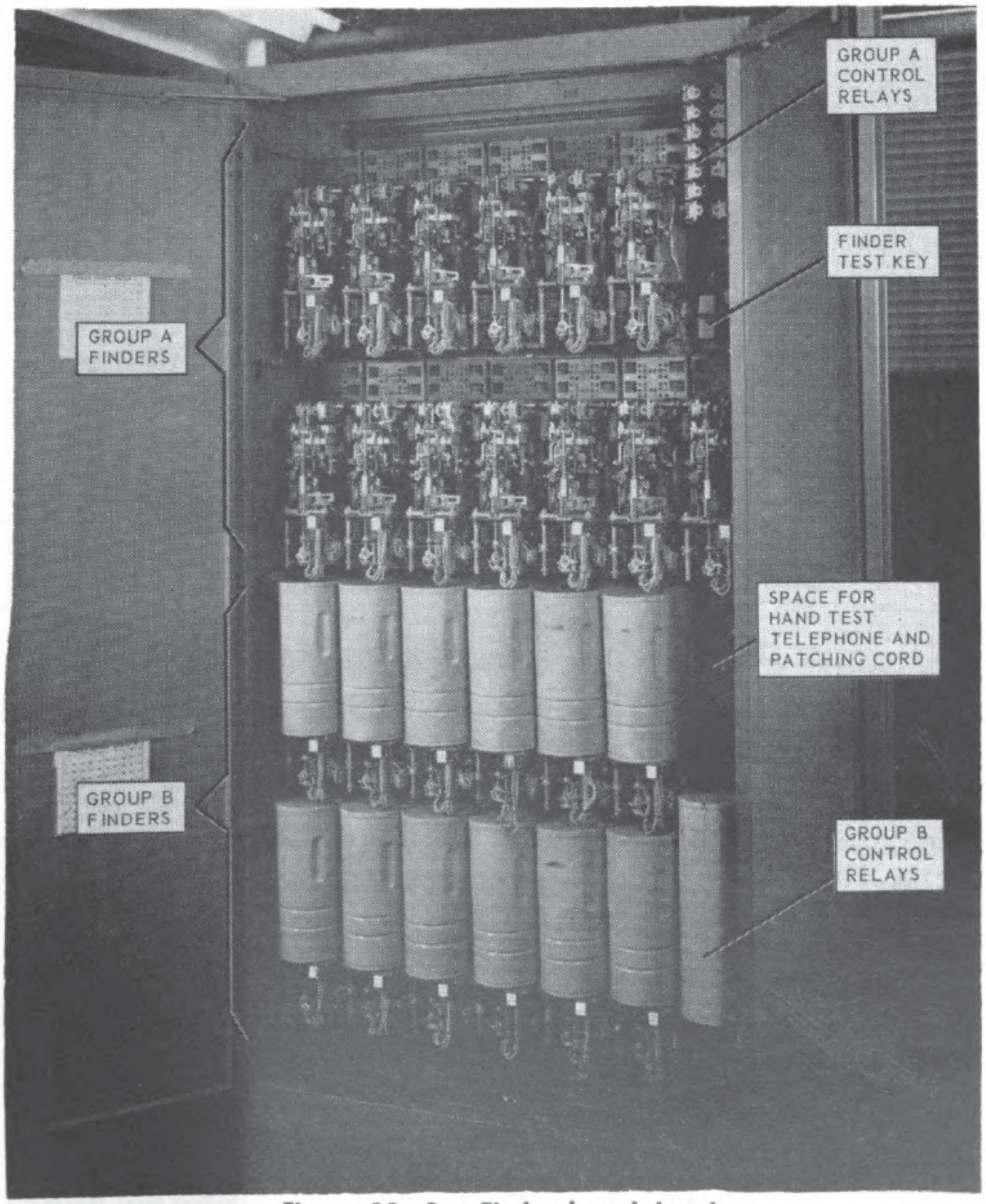


Figure 11—2.—Finder board (rear).

Line Relay

There is one line relay for each line (a total of 100), and one line transfer relay for each line that is used in connection with service provided by the attendant's cabinet. Each telephone line is permanently connected to a line relay (fig. 11–1) that serves the double purpose of a line relay and a cutoff relay. The relay coil consists of three windings and the relay operates in two steps.

On outgoing calls from a telephone line, the line relay is operated to the first step when the handset is removed from the cradle switch. This action closes certain contacts that cause the line-finder equipment to operate. The relay is operated to the second step when a finder switch connects with the line. This action disconnects the relay windings from the telephone line. The major functions of the line and cutoff relay on outgoing calls are to:

1. Mark (identify) the level in the finder switch vertical bank.
2. Mark the line in the finder switch control bank.
3. Cause the finder control equipment to operate the allotted finder.
4. Free the line of attachments when the finder seizes it.
5. Make the line busy to incoming calls.

On incoming calls to a telephone line, the line relay is operated to the second step by the connector switch. This action disconnects the line from the relay windings and prevents operation of the line finder equipment. The major functions of the line and cutoff relay on incoming calls are to:

1. Free the line of attachments.
2. Make the line busy to subsequent calls.

Finder Switch

The 25 finders (fig. 11–2) are 100-line Strowger switches of the jacked-in type designed to facilitate mounting and demounting. The principal functions of the finder

are (1) to find and (2) to connect a line that demands service to an idle connector. The operations of the finder are controlled by the finder control and distributor equipment.

Each finder has access to all lines but normally finds only the lines of its own group. When the handset of any telephone in the group is removed from the cradle switch, a preselected finder starts to search for the calling line. When the finder engages the calling line, this line is extended through to the connector switch associated with the finder. At this time, dial tone is connected to the line to indicate that dialing can commence. The major functions of the finder are to:

1. Elevate its wipers to the marked level.
2. Rotate its wipers onto the terminals of the calling line.
3. Cause the combination relay of the calling line to energize and to disconnect its windings from the line conductors.
4. Busy the calling line at the connector banks.
5. Extend the calling line to the connector switch.
6. Cause the finder control and distributor equipment to select the next idle finder for the next succeeding call.
7. Release at the termination of the call.

Line Grouping on Finder Banks

Preferential hunting is an important feature of the finder switches in the dial telephone system. Preferential hunting is accomplished by means of a "multiple" reversal between the banks of the two groups of finder switches. The line, although arranged in a group of 100 on the banks of the finder switches, are served in two 50-line groups, A and B. Under normal traffic conditions, each group has its individual allotment of finder switches. However, the full 100-line grouping is established when the traffic in groups A or B becomes abnormally heavy and its allotment of finder switches is momentarily in-

adequate. The finder switches of the associated group are then assigned to serve both the A and B groups until the traffic in the overloaded group becomes normal.

The principal advantage of this arrangement is that the individual lines of the two associated groups are so transposed in the banks of the finder switches that the hunting time of the finder switches of both groups is reduced to a minimum. Also, the possibility of lines in the lower levels "stealing" a finder switch from lines in the higher levels is negligible in cases of simultaneous calls.

The 25-line finders in the 100-line system are arranged in groups A and B. Group A comprises finders 1 to 13 inclusive, and group B comprises finders 14 to 25 inclusive. The lines are connected to the banks of the finder switches as follows:

Group A Finders (1 *to* 13)	*Group B Finders* (14 *to* 25)
level 0 — lines 01–00	level 0 — lines 11–10
level 9 — lines 91–90	level 9 — lines 21–20
level 8 — lines 81–80	level 8 — lines 31–30
level 7 — lines 71–70	level 7 — lines 41–40
level 6 — lines 61–60	level 6 — lines 51–50
level 5 — lines 51–50	level 5 — lines 61–60
level 4 — lines 41–40	level 4 — lines 71–70
level 3 — lines 31–30	level 3 — lines 81–80
level 2 — lines 21–20	level 2 — lines 91–90
level 1 — lines 11–10	level 1 — lines 01–00

All finders in group A are wired alike, and all finders in group B are wired alike. However, the lines in group B are in the reverse order from the lines in group A. Also, the lines 11–10, 21–20, 31–30, 41–40, 51–50 are normally served by group A finders only, and lines 01–00, 91–90, 81–80, 71–70, and 61–60 are normally served by group B finders only. Hence lines 11–10, 21-20, 31–30, 41–40, and 51–50 are on the lower levels of the group A finders; whereas, lines 01–00, 91–90, 81–80, 71–70, and 61–60 are on the lower levels of the group B finders.

For example, if a call is originated on any line in group

A, an idle finder in this group will step to level 1, 2, 3, 4, or 5, depending on which level the calling line appears. The finder will then cut in and stop on the calling line. Likewise, if a call is originated on any line in group B, the same action occurs in this group. Hence, the groups A and B finders normally step only to the fifth level respectively in their associated group.

However, if a call is originated on line 27 in group A at an instant when all of the finders in this group are busy an idle finder in group B will immediately step up to level 9, cut in, and stop on line 27. In the same manner, any other calls that originate in group A while all of the finders in this group are busy, will be served by the finders in group B. Conversely, calls originating in group B, while all of the finders in this group are busy, will be served by the finders in group A. Thus, the group A finders will step up to level 6, 7, 8, 9, or 10 as required.

Finder Control Relays

Each group of finders is provided with an associated group of finder control relays, mounted as a switch (fig. 11–2), and a corresponding set of distributor relays. The finder control relays control the vertical and rotary movements of the preselected finder. The finder control relays:

1. Seize the preselected finder at the initiation of a call.
2. Provide a pulsing circuit to the vertical magnet of the finder.
3. Stop vertical stepping of the finder when the vertical wiper engages the marked vertical bank contact corresponding to the level in which the calling line appears.
4. Provide a pulsing circuit for the rotary magnet of the finder.
5. Stop rotary stepping of the finder when the control wiper engages the marked contact of the called line.

6. Cause the wipers of the finder to rotate to the eleventh rotary position when the finder fails to find the calling line and to cause the distributor relays to allot the next idle finder to search for the line.
7. Cause the distributor relays to preselect the next idle finder in preparation for the next call.
8. Cause finders of the partner group to search for the calls normally served by its own group of finders, in case all of these finders become busy, or a fault develops in the group.

Finder Distributor Relays

The distributor relays associated with each group of finders assign the finder switches successively to the calls as they are originated. The distributor functions as a preselector by alloting, after a call is picked up, an idle finder for the next succeeding call. The distributor relays:

1. Connect the finder control switch to any one of the finders of the group.
2. Allot the next idle finder.

One distributor relay is provided for each finder switch. Thus, finders 1 to 13 inclusive in group A are associated with distributor relays *FD*1 to *FD*13 inclusive, and finders 14 to 25 inclusive in group B are associated with distributor relays *FD*14 to *FD*25 inclusive.

Fuse Panel

The fuse panel (fig. 11–1) contains all of the telephone fuses required for the protection of the switchboard equipment. These are three-ampere alarm-type indicating fuses.

The telephone (grasshopper) fuse is illustrated in figure 11–3. This fuse consists of an insulated support provided with a terminal at each end that is connected across the fuse block on the fuse panel. Metallic strips located on the front and back of this insulated support extend from each fuse terminal about half the length of

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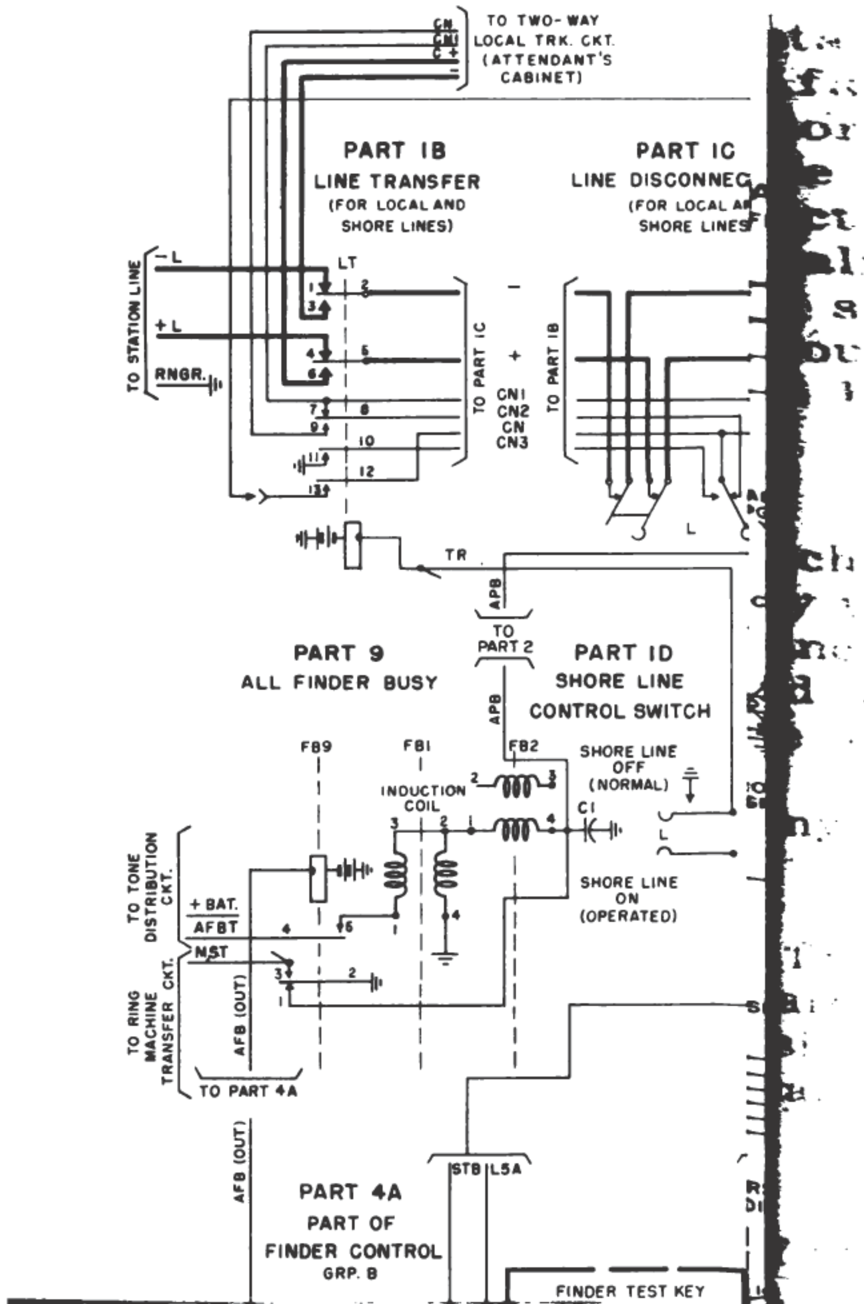

TO TWO-WAY
LOCAL TRK. CKT.
(ATTENDANT'S
CABINET)
CN
CN1
C+
PART 1B
LINE TRANSFER
(FOR LOCAL AND
SHORE LINES)
PART 1C
LINE DISCONNEC
(FOR LOCAL A
SHORE LINES
TO STATION LINE
-L
+L
RNGR.
LT
TO PART 1C
TO PART 1B
CN1
CN2
CN
CN3
TR
APB
TO
PART 2
PART 9
ALL FINDER BUSY
PART 1D
SHORE LINE
CONTROL SWITCH
FB9
FB1
FB2
INDUCTION
COIL
SHORE LINE
OFF
(NORMAL)
C1
SHORE LINE
ON
(OPERATED)
TO TONE
DISTRIBUTION
CKT.
+ BAT.
AFBT
MST
TO RING
MACHINE
TRANSFER CKT.
AFB (OUT)
TO PART 4A
STB
L5A
PART 4A
PART OF
FINDER CONTROL
GRP. B
FINDER TEST KEY

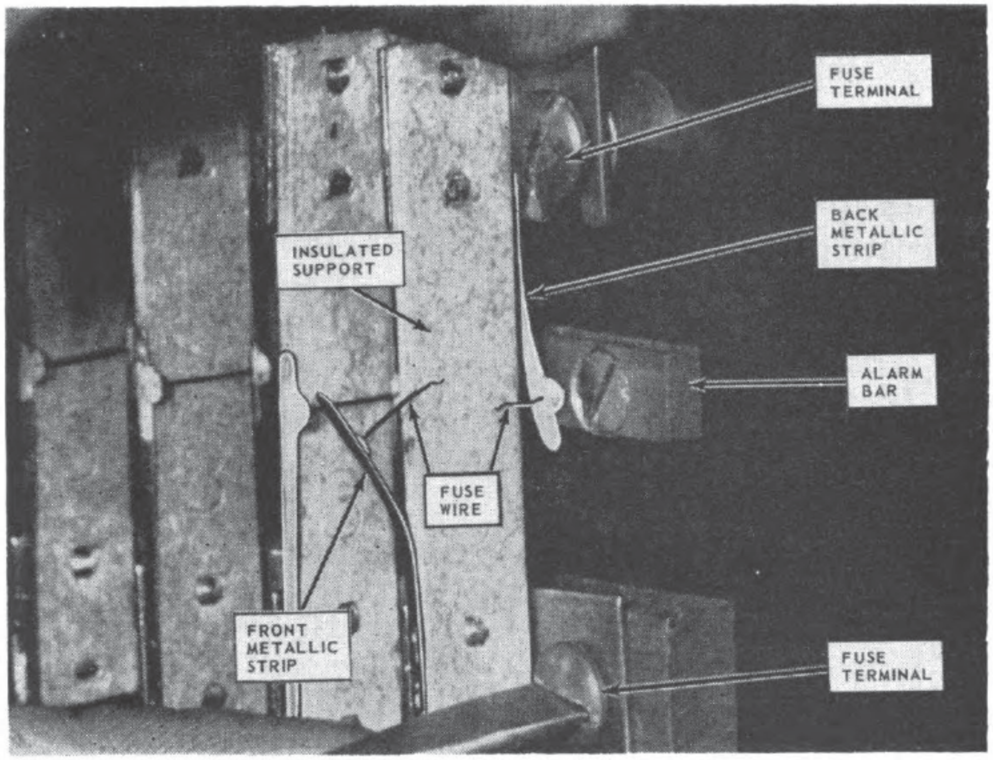


Figure 11—3.—Telephone fuse.

the support. The free ends of these metallic strips are tied together by fuse wire, thereby placing these strips under slight spring tension. When the fuse blows, the back metallic strip springs backward to make contact with the alarm bar, thereby completing an alarm circuit. The front metallic strip springs forward to indicate the blown fuse.

FINDER, FINDER CONTROL, AND LINE EQUIPMENT CIRCUIT

The finder, finder control, and line equipment circuit (fig. 11–4) is designed to select one of 100 lines, which may be initiating a call, and to connect the calling line to an idle succeeding switch, which may be either a connector or a selector. The group A finders only are considered in the circuit analysis because the operation of the group B finders is similar. Also, only one line circuit is considered because the explanation would be the same for any line served by the line finder. The relays in the figure are designated by the letters appearing above them

and by the numbers of the parts in which they are located. For example, relay *L* (part 2) will be designated as relay *L*2.

Various telephone relays are provided with working names that identify their functions and that are useful in locating troubles in the associated circuits. The working names of the finder relays in the 100-line system are:

*E*4.....Finder control start relay
*G*4.....Timer start relay
*F*4.....All trunks busy relay
*T*4.....Finder control holding relay
*A*4.....Pulsing relay
*B*4.....Normal finder control kickoff relay
*H*4.....First transfer relay
*J*4.....Second transfer relay
*D*4.....Finder control timer relay
*L*4.....Finder control timer relay
*K*4.....Fifth level mark relay
*U*4.....Call blocked kickoff relay
*C*4.....Auxiliary call blocked relay
FD.... Preselect-the-next-idle-finder relay
*D*6.....Finder start relay
*C*6.....Cut through relay
*L*2.....Line relay (no working name)
*RS*1*A* ..Group A reset relay (prepares the operating circuit to relay *FD*1 when the system is re-energized after a call-blocked condition or after the power to the system has been interrupted).
*RS*1*B* ..Group B reset relay (prepares the operating circuit to relay *FD*14 when the system is re-energized after a call-blocked condition or after the power to the system has been interrupted).
*RS*2*A* ..Group A reset relay (prepares the operating and first lock circuits to relay *FD*1 when relay *FD*13 is operated).

RS2B . . Group B reset relay (prepares the operating and the first lock circuits to relay *FD*14 when relay *FD*25 is operated).

Functions

On calls from a line station, the finder, finder control, and line equipment circuit:

1. Operates the line relay partially from the calling station's loop.
2. Starts the finder that has been preselected.
3. Elevates the wipers to the level on which the calling station's line appears.
4. Rotates the wipers to the contacts to which the calling station's line is connected.
5. Extends the calling station's line to the succeeding switch, operates the line relay completely, and makes the calling station's line busy to other calls.
6. Operates the distributor to select the next idle finder for any succeeding call.
7. Restores the finder on completion of the call.
8. Rotates the wipers of the finder to the eleventh rotary position when the finder fails to find the calling line and causes the distributor to allot the next idle finder to the call.
9. Restores the finder and transfers the call to the partner group when the line is not found within a specified time; transfers to the partner group when there is an ATB condition.

On calls to a line station from a connector, the finder, finder control, and line equipment circuit.

1. Makes the dialed line busy.
2. Clears the line of attachments.

On calls from the trunk circuit, the functions of the finder, finder control, and line equipment circuit are similar to those described for calls to a line station.

The two types of calls encountered in this telephone system are COMMISSIONING calls and NORMAL calls. A commissioning call is the first call through the exchange when

the system is reenergized after any abnormal condition has caused interruption of the power supply to the system. A normal call is any other call through the exchange.

Finding the Calling Line

SEIZURE.—On a COMMISSIONING CALL the system is energized by operating the power switch (not shown) to the ON position. The power switch is usually mounted on the side or rear of the power panel. This action operates the $F4$ relays in group A and group B finders (fig. 11–4). The metering (positive) ground for the operation of the $F4$ relays originates through contacts 3-4 of relay Z_c in the connector (fig. 11–7), over the G1 lead, through the finder VON springs 6–7 (fig. 11–4), over the ATBG lead, through the group A finder blocked key, to relay $F4$, and negative battery. If a finder is free, the ground through contacts 3–4 of relay Z_c in the connector keeps relay $F4$ in the finder operated. This ground is called a METERING ground and there are 13 of these grounds in group A and 12 in group B when all finders are free. As calls are made and a finder is busy, a ground is removed from relay $F4$. This action is explained later.

When a calling party removes the handset, the d-c loop is completed from ground through contacts 1–2 of relay $FB9$ (fig. 11–4), to winding 2 of relay $L2$, through contacts 5-6 of relay $L2$, to the $+L$ lead, to the line disconnect key, through the line station cradle switch and transmitter, back through the $-L$ lead, through the line disconnect key, through contacts 7–8 of relay $L2$, to winding 3 and winding 1 of relay $L2$, to negative battery. The bucking action of the coils allows relay $L2$ to operate only partially.

RELAY $L2$ OPERATES PARTIALLY:

1. X contacts (1–2) place negative battery on the C lead to the finder banks to mark this calling line.

2. *X* contacts (3–4) place ground on the SLM lead through its contacts 9–10 to the start and level marking circuit (part 3). Ground on the SLM group A lead places direct ground on the vertical banks of the finder (part 6) to mark the level in which the calling line will be found. This ground completes a circuit through the associated 2,000-ohm resistor (No. 1 in this example) by way of the STA lead, through contacts 4–5 of relay *F*4, through relay *E*4 to negative battery.

RELAY *E*4 OPERATES:

1. Contacts 1–2 complete a circuit to relay *FD*1. The circuit is from ground, contacts 6–7 of relay *B*4, over the RS1 lead, contacts 5–6 of relay *FD*13, contacts 5–6 of the intermediate *FD* relays, contacts 5–6 of relay *FD*1 (released), over the FDA lead, contacts 1–2 of relay *B*4, contacts 1–2 of relay *E*4, (operated), over the *RS*3 lead, contacts 1–2 of relay *RS*1*A* (released), relay *FD*1, to negative battery.

RELAY *FD*1 OPERATES:

1. X contacts (1–2) complete its lock circuit through relay *RS*1*A* and contacts 6–7 of relay *F*4 to ground.

RELAY *RS*1*A* OPERATES:

1. Contacts 2–3 prepare a circuit over the FDA lead for future use by relay *B*4. Relay *B*4 normally (normal calls) completes the circuit to relay *FD*1. Relay *E*4 only completes the circuit to relay *FD*1 on a commissioning call. This action is explained later on a normal call.
2. Contacts 4–5 complete the operating circuit to relays *G*4 and *T*4.

From this point on, the sequence of operation for a commissioning call and a normal call are identical.

On a NORMAL CALL the finder control relay *F*4, the reset relay *RS*1*A*, and one of the finder distributor relays,

*FD*1 (in this case) are operated. When a calling party removes the handset the d-c loop is completed from ground through contacts 1–2 of relay *FB*9 (fig. 11–4), to winding 2 of relay *L*2, through contacts 5–6 of relay *L*2, to the $+L$ lead, to the line disconnect key, through the line station cradle switch and transmitter, back through the $-L$ lead, through the line disconnect key, through contacts 7–8 of relay *L*2 to winding 3 and winding 1 of relay *L*2, to negative battery. The bucking action of the coils allows relay *L*2 to operate only partially.

RELAY *L*2 OPERATES PARTIALLY:

1. *X* contacts (1–2) place negative battery on the C lead to the finder banks to mark this calling line.
2. *X* contacts (3–4) place ground on the SLM lead to the start and level marking circuit (part 3). Ground on the SLM group A lead places direct ground on the vertical banks of the finder (part 6) to mark the level in which the calling line will be found. This ground completes a circuit through the associated 2,000-ohm resistor (No. 1 in this example) by way of the STA lead, through contacts 4–5 of relay *F*4, through relay *E*4 to negative battery.

RELAY *E*4 OPERATES:

1. Contacts 3–4 complete a circuit to relay *T*4 through contacts 4–5 of relay *RS*1*A* (operated).
2. Contacts 5–6 complete a circuit to relay *G*4 through contacts 4–5 of relay *RS*1*A* (operated).

RELAY *G*4 OPERATES:

1. Contacts 1–2 complete a circuit to relay *K*4.
2. Contacts 3–4 place ground on the *TST* lead to start the timers.
3. Contacts 5–6 prepare a circuit on the *FC*1 lead to relay *D*4.
4. Contacts 7–8 prepare its lock circuit.

RELAY $T4$ OPERATES:

1. Contacts $1B$–$2B$ complete the lock circuit to relay $G4$.
2. Contacts $1T$–$2T$ place ground on the VERTICAL lead.
3. Contacts $3T$–$4T$ complete a circuit through contacts 8–9 of relay $FD1$ by way of the FST lead to finder relay $D6$.
4. Contacts $5T$–$6T$ prepare (ground) a circuit to relay $J4$.
5. Contacts $3B$–$4B$ prepare its lock circuit.
6. Contacts $5B$–$6B$ complete a multiple ground circuit to relay $F4$. (The other ground is a metering ground through contacts 3–4 of relay Z_c in the connector.)
7. Contacts $7B$–$8B$ prepare a circuit to relays $A4$ and $H4$.

RELAY $K4$ OPERATES:

1. Contacts 1–2 open its shorted winding.
2. Contacts 5–6 prepare a circuit to relay $H4$.
3. Contacts 7–8 place ground on the $L5AG$ lead. Ground on the $L5AG$ lead places ground on the fifth level of the group A vertical finder banks (part 6) so that the group A finders will not search above the fifth level.
4. Contacts 9–11 complete the lock circuit to relay $T4$.

VERTICAL HUNTING.—The finder is now prepared for vertical hunting ($L2$, $E4$, $G4$, $T4$, $D6$, and $K4$ energized in addition to $F4$, $RS1A$, and $FD1$, which are normally operated).

RELAY $D6$ OPERATES:

1. Contacts $1T$–$2T$ open the bridge between the C lead and the G (guard) lead.
2. Contacts $3T$–$4T$ prepare a circuit through the TEST lead to the first transfer relay $H4$.
3. Contacts $5T$–$6T$ prepare a circuit to the rotary magnet.

4. Contacts $7T$–$8T$ complete a circuit to the vertical magnet.
5. Contacts $9T$–$10T$ prepare a circuit on the *INT* lead.
6. Contacts $2B$–$3B$ place ground on the C lead.
7. Contacts $4B$–$5B$ complete a circuit through the 500-ohm N.I. (noninductive) resistance across the $-L$ and $+L$ leads. This action preseizes the associated connector (not shown).
8. Contacts $6B$–$7B$ prepare a circuit to relay $C6$.

NOTE: The connector circuit is discussed subsequent to the finder circuit. However, because dial tone passes through the connector, it is important at this time to understand part of the action that occurs when the connector is preseized. The operating circuit of relay A_c is completed when the connector (fig. 11–7) is preseized by contacts $4B$–$5B$ of relay $D6$. The circuit is by way of positive ground, contacts 5–6 of relay G_c, winding 2 of relay A_c, the $+ L$ lead, contacts 8–9 of relay D_c, out through the $+L$ lead, contacts $4B$–$5B$ of relay $D6$, the 500 ohm N.I. winding of relay $C6$, out through $-L$ to contacts 5–6 of relay D_c, to winding 1 of relay A_c and to negative battery. Contacts 2–3 of relay A_c complete the operating circuit to relay B_c. Contacts 11–12 of relay B_c complete the operating circuits to relays C_c and G_c. Contacts 4–6 of relay G_c complete the first holding circuit to relay A_c over the dial tone lead through *SJ*15 (switch jack 15). Positive ground is by way of SJ15.

VERTICAL MAGNET OPERATES:

1. Interrupter springs 1–2 complete a circuit on the *INT* lead to pulsing relay $A4$.
2. Finder steps to the first level from the normal (no signal) position.

VON SPRINGS OPERATE:

1. Springs 1–2 prepare a circuit to the RLS (release) magnet.
2. Springs 3–4 prepare ground for the *G* lead.

3. Springs 6–7 open the $G1$ lead to remove one of the metering grounds from $F4$.

RELAY $A4$ OPERATES:

1. Contacts 2–3 open the circuit to the vertical magnet.

VERTICAL MAGNET RESTORES MOMENTARILY AT THE FIRST LEVEL:

1. Interrupter springs 1–2 open the circuit to relay $A4$.

RELAY $A4$ RESTORES:

1. Contacts 2–3 complete the circuit to the vertical magnet.

The vertical magnet and pulsing relay, $A4$, continue to oscillate, stepping the finder vertically upward one level at a time until the VERTICAL WIPER finds ground on the vertical bank. When the VERTICAL WIPER finds a grounded level, a circuit is completed through the TEST lead to winding 1 of the first transfer relay, $H4$. This winding is in series with relay $A4$.

RELAY $A4$ OPERATES:

1. Contacts 2–3 open the circuit to the vertical magnets.

VERTICAL MAGNETS RESTORE:

1. Springs 1–2 remove the ground from one end of relay $H4$.

RELAY $H4$ OPERATES PARTIALLY:

1. X contacts (1–2) complete a circuit to winding 2.

RELAY $H4$ OPERATES COMPLETELY:

1. Contacts 3–4 open the circuit to relay $A4$.
2. Contacts 7–8 prepare a circuit to the rotary magnets.

This action transfers the vertical stepping circuit to the rotary stepping circuit. However, it does not complete the circuit.

RELAY $A4$ RESTORES:

1. Contacts 2–3 complete a circuit to the rotary magnets.

ROTARY HUNTING.—The finder is now prepared for

rotary hunting (*L*2, *E*4, *G*4, *H*4, *K*4, *D*6, and *T*4 operated). The finder hunts for negative battery placed on the C contact of the calling party by relay *L*2.

ROTARY MAGNET OPERATES:

1. Interrupter springs 1-2 complete a circuit on the *INT* lead to the pulsing relay, *A*4.
2. Finder rotates its wipers to the first contact.

RELAY *A*4 OPERATES:

1. Contacts 2-3 open the circuit to the rotary magnet.

ROTARY MAGNET RESTORES:

1. Springs 1-2 open the circuit to pulsing relay *A*4.

RELAY *A*4 RESTORES:

1. Contacts 1–2 complete the circuit to the rotary magnet.

This action continues until the *C* wiper encounters negative battery on the *C* contact of the calling station. Negative battery is placed on the *C* contact by line relay, *L*2, of the calling station.

ROTARY MAGNET OPERATES:

1. C wiper encounters negative battery.
2. Springs 1–2 complete the circuit to pulsing relay, *A*4.

C WIPER ENCOUNTERS NEGATIVE BATTERY:

1. *C* wiper completes the circuit to relay *J*4 and winding 1 of relay *L*2 in series. Relay *L*2 now operates completely and completes it's lock circuit.

RELAY *L*2 OPERATES COMPLETELY:

1. Contacts 5–6 and 7–8 remove all attachments from across the line.
2. Contacts 9–10 remove ground from the *SLM* lead and relay *E*4.

RELAY *J*4 OPERATES:

1. Contacts 1–2 open the circuit to the rotary magnet.
2. Contacts 2–3 prepare a circuit over the *SW* lead to relay *C*6.

ROTARY MAGNET RESTORES:

1. Springs 1–2 open the circuit to relay $A4$.

RELAY $A4$ RESTORES:

1. Contacts 2–3 complete the circuit to relay $C6$.

In this example the vertical magnets have stepped the vertical wiper UP to the marked level, and the rotary magnets have stepped the rotary wipers IN to the terminals to which the calling subscriber's line is connected.

SWITCH THROUGH.—The lines from the calling station are now prepared to switch through to the succeeding switch ($L2$, $T4$, $H4$, $K4$, $J4$, $D6$, and $G4$ operated).

RELAY $C6$ OPERATES:

1. Contacts $5T$–$6T$ and $7T$–$8T$ switch the $+L$ and $-L$ lines from the calling station through to the succeeding switch (associated connector or selector switch not shown), completing dial tone. The circuit (fig. 11–7) is over the DIAL TONE lead, through $SJ15$ through contacts 4–6 or relay G_c (operated), to winding 2 of relay A_c, through contacts 8–9 of relay D_c, over the $+L$ line, through the hookswitch of the calling telephone, back over the $-L$ line, through contacts 5–6 of relay D_c, and through winding 1 of relay A_c, to negative battery. This action also completes the second holding circuit to relay A_c in the connector. Ground for the second holding circuit of relay A_c originates at $SJ15$ over the dial tone lead.
2. Contacts $7B$–$8B$ prepare a circuit from the EC lead to the succeeding switch (not shown).
3. Contacts $3T$–$4T$ place ground (originating at contacts 7–8 of relay B_c in the connector) over the C lead to complete its (relay $C6$) first lock circuit.
4. Contacts $5B$–$6B$ complete a circuit to the C lead to place direct ground (from contacts 7–8 of relay B_c in the connector) on relay $L2$ and to busy the calling station equipment. The ground on

relay *L*2 completes its second lock circuit. Also, the ground on the test lead through contacts 3*T*–4*T* of relay *D*6 shunts relay *J*4 causing it to restore.

5. Contacts 3*B*–4*B* place ground on the *G* lead through VON springs 3–4 to operate relay *B*4.
6. Contacts 1*B*–2*B* open the circuit to the RLS magnet.

SELECTING THE NEXT IDLE FINDER (NORMAL KICK-OFF CONDITION).—The equipment is prepared to select the next idle finder (*L*2, *T*4, *H*4, *K*4, *J*4, *C*6, *D*6, and *G*4 operated). Ground on the *G* lead completes a circuit to relay *B*4.

RELAY *B*4 OPERATES:

1. Contacts 2–3 complete the operating circuit to the next *FD* relay in the chain (*FD*2) through the FDA lead.
2. Contacts 4–5 open the circuit to relay *T*4.
3. Contacts 8–9 open the circuit to relay *G*4. The (second) *FD*2 relay (which can be *FD*2 through *FD*12) operates, assuming that relay *FD*1 is already operated.

RELAY *FD*2 OPERATES:

1. X contacts (1–2) complete its locking circuit in series with reset relay *RS*1*A*.
2. Contacts 3–4 open the circuit to the preceding *FD*1 relay.
3. Contacts 6–7 prepare the operating circuit to the (next) *FD*3 relay in the chain.
4. Contacts 8–9 prepare the *FST* lead to the second finder.
5. Contacts 10–11 prepare the *G* lead to the second finder.

RELAY *T*4 RESTORES:

1. Contacts 1*T*–2*T* remove the ground from the *SW* lead.

2. Contacts $3T$–$4T$ open the operating circuit of the *FST* lead to relay $D6$.
3. Contacts $5T$–$6T$ open the circuit to relays $J4$ and $L2$.
4. Contacts $1B$–$2B$ open the circuit to relay $G4$.
5. Contacts $5B$–$6B$ remove a multiple ground from relay $F4$.

RELAY $G4$ RESTORES:

1. Contacts 1–2 open the circuit to relays $K4$ and $H4$.
2. Contacts 3–4 open the *TST* lead to the timer relays.
3. Contacts 5–6 open the $FC1$ lead to the timer relays.

RELAY $FD1$ RESTORES: (See item 2 of relay $FD2$ operates.)

1. Contacts 3–4 prepare a circuit to relay $RS2A$.
2. Contacts 5–6 prepare a circuit to the $FD3$ relay.
3. Contacts 10–11 open the G lead to relay $B4$.

RELAY $D6$ RESTORES: (See item 2 of relay $T4$ restores.)

1. Contacts $1T$–$2T$ prepare the restore circuit.
2. Contacts $2B$–$3B$ remove a multiple ground from the C lead (the other ground is supplied by the preseized switch).
3. Contacts $4B$–$5B$ remove the preseizing 500-ohm N.I. resistance from across the $-L$ and $+L$ lines.

The relays have restored and the finder control circuit is now at normal. The circuit is ready to find another line. The next call will be found by the second finder.

NEXT FINDER BUSY.—Ground on the G lead guards a finder and prevents it from being seized for another call. If any finder is busy, ground is maintained on the G lead of that *FD* relay. This ground is through contacts 4–5 of relay Z_c in the connector, over the G lead to the finder VON springs 3–4, out over the G lead, to contacts 10–11 of the *FD* relay, to relay $B4$ and negative battery. This

action puts a hold on relay *B*4 and prevents the finder from being seized for another call.

For example, if the second finder were busy, ground would be maintained on the *G* lead of the second *FD* relay. With the second *FD* relay operated, a circuit is prepared through contacts 6–7 to the third *FD* relay and the circuit is opened through contacts 3–4 to the first *FD* relay. Contacts 10-11 complete a circuit to relay *B*4.

Relay *B*4 operates and contacts 2–3 complete a circuit to the third *FD* relay through contacts 5–6 of the first *FD* relay and contacts 6–7 of the second *FD* relay. The third *FD* relay will operate and allot the call to the third finder. If the third finder were busy, the search for an idle finder would continue in a similar manner.

DISTRIBUTOR OPERATION WHEN RELAY *FD* 13 (LAST) OPERATES.—When the next to the last finder (finder 12) is used, contacts 2–3 of relay *B*4 will complete a circuit to the *FD*13 relay.

*FD*13 RELAY OPERATES:

1. *X* contacts (1–2) complete its locking circuit in series with relays *RS*2A and *RS*1A.
2. Contacts 3–4 open the circuit to relay *FD*12.
3. Contacts 6–7 prepare a circuit to relay *FD*1.
4. Contacts 8–9 prepare the *FST* lead to the last finder.
5. Contacts 10–11 prepare the *G* lead to the last finder.

RELAY *FD*12 RESTORES: (See item 2 above.)

RELAY *RS*2A OPERATES: (See item 1 above.)

1. Contacts 1–2 prepare a lock circuit to relay *FD*1.
2. Contacts 3–4 prepare the operating circuit to relay *FD*1.

When another call is initiated, the last finder finds the line and places ground on the *G* lead to operate relay B4, which will operate relay *FD*1.

RELAY *FD*1 OPERATES:

1. X contacts (1–2) complete its locking circuit in series with relay *RS*1A.

2. Contacts 3–4 open the circuit to relays *RS*2A and *FD*13.
3. Contacts 5–6 open its initial operating circuit.
4. Contacts 6–7 prepare a circuit to relay *FD*2.
5. Contacts 8-9 prepare the *FST* lead to the first finder for the next call.
6. Contacts 10–11 prepare the *G* lead to the first finder for the next call.

RELAY *FD*13 RESTORES: (See item 2 above.)

1. Contacts 3–4 complete a multiple circuit to relay *RS*1*A* and a lock circuit to relay *FD*1.

RELAY *RS*2*A* RESTORES:

1. Contacts 1–2 open the multiple circuit to relay *FD*1.

Relay *FD*1 remains operated through its lock circuit in series with relay *RS*1A, which also remains operated.

RELEASE.—When the calling party releases, the d-c loop is opened to the connector switch, which opens the circuit to windings 1, 2, and 3 of relay *L*2. Contacts 1–2 of relay *L*2 open the circuit to the *C* lead to remove ground, which was initially established through contacts 1–2 of relay *FB*9 by way of the APB lead to winding 2 of relay *L*2. The removal of ground from the *C* lead opens the circuit to relays *L*2 and *C*6.

RELAY *L*2 RESTORES:

Restores relay *L*2 to normal.

RELAY *C*6 RESTORES:

1. Contacts 5*T*–6*T* and 7*T*–8*T* open the $+L$ and $-L$ lines to the succeeding switch.
2. Contacts 1*B*–2*B* complete a circuit to the RLS magnet through VON springs 1–2.
3. Contacts 3*B*–4*B* open a multiple circuit to the *G* lead.
4. Contacts 5*B*–6*B* open the *C* lead to the succeeding switch.
5. Contacts 7*B*–8*B* open the *EC* lead to the succeeding switch.

Ground is maintained on the *G* lead from the VON springs 3–4 to prevent this finder switch from being seized during release.

RELEASE MAGNET OPERATES:

1. Release signal springs 1–2 complete a circuit to ground the *FR SIG* lead.
2. The release magnet permits the finder to restore to normal.

VON SPRINGS RESTORE:

1. Springs 1–2 open the *RLS* magnet circuit.
2. Springs 3–4 remove ground from *G* lead.
3. Springs 6–7 complete a circuit on the *G*1 lead to relay *F*4.

RELEASE MAGNET RESTORES:

1. Release-signal springs 1–2 remove ground from the *FR SIG* lead.

The finder is now ready for use again.

ALL TRUNKS BUSY.—As previously stated, the *RS*1*A*, *F*4, and one of the *FD* relays are operated at all times for normal calls. For example, the *FD*1 and *RS*1A relays, which are in series, are held operated through ground at contacts 6–7 of relay *F*4. The *F*4 relay receives a multiple source of ground from the *ATBG* lead.

The *ATBG* lead is multiple-connected (paralleled) to all the succeeding switches associated with this finder group. The succeeding switch, when idle, completes a circuit from the *ATBG* lead to the *G*1 lead of the finder associated with it. As soon as the finder begins to search for a line, ground is removed from the *G*1 lead and the *ATBG* lead.

When all finders but one are busy, the *F*4 relay is held operated by the one remaining ground on the *ATBG* lead. When the last free finder begins to search for a line, the final ground is removed from the *ATBG* lead. Relay *F*4 does not restore because it is held operated from ground by contacts 5*B*–6*B* of relay *T*4. When the line has been located and the finder controls have been restored, relay *T*4 is restored and the circuit is opened to relay *F*4.

RELAY *F*4 RESTORES:

1. Contacts 1–2 prepare a circuit to the *AFB* (in) and the *AFB* (out) leads to relay *FB*9.
2. Contacts 3–4 transfer all group A calls to the group B controls. Contacts 3–4 connect the *STA* and *STB* leads together to complete the circuit to relay *E*4 in group B.
3. Contacts 4–5 open the circuit to relay *E*4 in group A.
4. Contacts 6–7 open the circuit to relay *RS*1*A* and the *FD* relay.
5. Contacts 10–11 open the fifth level lead mark circuit of the group B finder.

RELAY *RS*1*A* RESTORES AND ALSO THE *FD* RELAY RESTORES.

Calls that are normally handled by the group A finders place ground on the *STA* lead, and the group B finders place ground on the *STB* lead. This action opens the circuit to relay *E*4 in group A and completes the circuit to relay *E*4 in group B so that group B handles all the calls. The group B finders will search for all calls because the *STA* lead is connected to the *STB* lead. Contacts 10–11 of relay *F*4 remove ground over the *L*5*BG* lead so that ground will not be placed on the fifth level of the group B finders. This action makes it possible for the group B finders to search above the fifth level for calls that are normally handled by the group A finders. When any one of the group A finders becomes free, ground is placed on the *ATBG* lead through contacts 3–4 of relay Z_c in the connector to complete a circuit to relay *F*4 in group A.

RELAY *F*4 OPERATES:

1. Contacts 1–2 open the circuit between the *AFB* (in) and the *AFB* (out) leads.
2. Contacts 3–4 open the circuit between the *STA* and the *STB* leads.
3. Contacts 4–5 prepare a circuit to relay *E*4.
4. Contacts 6–7 prepare a circuit to relay *RS*1*A*.
5. Contacts 10–11 prepare a circuit to the *L*5*BG* lead.

When a call is initiated, the circuit is completed to relay *E*4, which operates and completes a circuit to relay *FD*1 from ground at contacts 6–7 of relay *B*4. The circuit is completed through the 5–6 contacts of the *FD* relays, the 1–2 contacts of relay *B*4, the 1–2 contacts of relay *E*4, the 1–2 contacts of relay *RS*1*A*, the *FD*1 relay, and negative battery. The first finder is allotted to this call. However, if the first finder is busy, the distributor will operate as previously explained (next finder busy) until an idle finder is found.

FAILURE OF FINDER TO STEP (CALL BLOCKED KICKOFF).—Relays *L*2, *E*4, *T*4, *K*4, *D*6, and *G*4 are operated. Contacts 3–4 of relay *G*4 (operated) completes a circuit over the *TST* lead to start the timers. If the finder allotted to a call is defective and will not step (when both groups of finders are available), after a short lapse of time (from 0 to 7 seconds) a ground pulse is supplied to the *FC*1 lead from the timer relays to complete a circuit to relay *D*4. Relays *C*4, *D*4, *L*4 and *U*4 operate only during a call-blocked kickoff condition. Assume finder 3 to be defective.

RELAY *D*4 OPERATES:

1. Contacts 1–2 complete its lock circuit.
2. Contacts 3–4 prepare a circuit from the *FC*2 lead to relay *L*4.

After another interval (4 seconds later), a ground pulse will be supplied to the *FC*2 lead from the timer relays to complete a circuit to relay *L*4. A call block kickoff results if relay *B*4 does not operate within an interval of from 4 to 11 seconds after a normal call is initiated.

RELAY *L*4 OPERATES:

1. Contacts 1–2 open the operating circuit to relay *D*4.
2. Contacts 3–5 complete its lock circuit and a circuit to relay *U*4.
3. Contacts 4–5 open the lock circuit to relay *D*4.

RELAY *D*4 RESTORES:

1. Contacts 3–4 open the operating circuit to relay *L*4.

RELAY *U*4 OPERATES:

1. Contacts 1*T*–2*T* open the incomplete lock circuit to relay *U*4 of group *B* through the *FB* lead.
2. Contacts 5*T*–6*T* complete the operating circuit of the next *FD* relay (*FD*4) circuit through windings 1 and 2 of relay *C*4. Relay *C*4 is not operated because its windings are in opposition. This operating circuit to the *FD*4 relay is by way of contacts 1–2 of relay *C*4, contacts 3–4 of relay *K*4, contacts 1–2 of relay *B*4, and the *FDA* lead.
3. Contacts 7*T*–8*T* complete a circuit through the *FBL* lead to the group A finder blocked alarm lamp.
4. Contacts 1*B*–2*B* open the circuit from the *ATBG* lead of group A to remove any multiple grounds on this circuit from relay *F*4.
5. Contacts 3*B*–4*B* complete a circuit across the *A* and the *AG* leads of the fuse alarm relay for an audible alarm.
6. Contacts 5*B*–6*B* complete its lock circuit through the *FR* lead and the *AB* lead by way of contacts 1*T*–2*T* of relay *U*4 of group B (part 4A) to ground on the *ATBG* lead of group B (part 4).

RELAY *FD*4 OPERATES:

1. *X* contacts (1–2) complete its lock circuit and shunt winding 1 of relay *C*4.
2. Contacts 3–4 open the lock circuit of relay *FD*3.
3. Contacts 6–7 prepare a circuit to relay *FD*5.
4. Contacts 8–9 prepare the operating circuit (*FST* lead) of relay *D*6 of finder 4.
5. Contacts 10–11 prepare the operating circuit (*G* lead) of relay *B*4 for finder 4.

When the lock circuit to relay *FD*4 is completed, a 200-ohm ground is placed on the inside terminal of winding 1

of relay *C*4, thereby shunting this winding and decreasing the current in it. Thus, the windings of relay *C*4 are now unbalanced.

RELAY *C*4 OPERATES:

1. Contacts 1–2 open the operating circuit of relay *FD*4.
2. Contacts 2–3 complete a slow-release feature to winding 1 (used when relay *C*4 restores).
3. Contacts 4–5 open the circuits to relays *G*4 and *T*4.
4. Contacts 5–6 complete a multiple circuit to relay *F*4.

RELAY *FD*3 RESTORES:

1. *X* contacts (1–2) open its incomplete lock circuit.
2. Contacts 5–6 prepare the starting circuit to relay *FD*5.
3. Contacts 8–9 further open the *FST* lead to relay *D*6 of finder 3.

RELAY *T*4 RESTORES:

1. Contacts 1*T*–2*T* open the stepping circuit to the vertical magnets of finder 3.
2. Contacts 3*T*–4*T* open the FST lead to relay *D*6 of finder 3.
3. Contacts 5*B*–6*B* open the hold circuit of relay *F*4.

RELAY *G*4 RESTORES:

1. Contacts 1–2 open the operating circuit of relay *K*4, the lock circuit of relay *L*4, and the operating circuits of relays *U*4 and *C*4.
2. Contacts 3–4 open the *TST* lead to stop the timer relays.
3. Contacts 7–8 open its incomplete locking circuit.

RELAY *L*4 RESTORES.

RELAY *K*4 RESTORES:

1. Contacts 7–8 remove the ground marking the fifth vertical contact in the group A line-finder vertical banks through the *L5AG* lead.

RELAY $C4$ (SLOW RELEASE) RESTORES:

1. Contacts 5–6 open the second holding circuit to relay $F4$.

RELAY $F4$ RESTORES:

1. Contacts 1–2 prepare an operating circuit to relay $FB9$.
2. Contacts 3–4 prepare an operating circuit from the *STA* lead to relay $E4$ in the group B finder control.
3. Contacts 4–5 open the operating circuit to relay $E4$.
4. Contacts 6–7 open the operating circuit of relay $RS1A$, in series with the locking circuit of relay $FD4$.
5. Contacts 8–9 open the incomplete operating circuit to the next *FD* relay to prevent cycling of the *FD* relays.
6. Contacts 10–11 remove the fifth level mark to the group B vertical finder banks.

Relay $F4$ will remain nonoperated as long as relay $U4$ (remaining operated) holds the circuit open to relay $F4$.

When the blocked (defective) finder is determined, the FINDER RESET KEY is operated to route the calls to the group A finders again. Operating the finder reset key opens the circuit to relay $U4$.

RELAY $U4$ RESTORES:

1. Contacts $1B$–$2B$ complete multiple circuits to relay $F4$.

RELAY $F4$ OPERATES:

1. Contacts 4–5 prepare a circuit from the *STA* lead to relay $E4$.
2. Contacts 6–7 prepare a circuit to relay $RS1A$.

The defective finder is repaired or removed from the jack to prevent further blocking. If a finder should fail to step when only the group A finders are available, the circuit analysis will be as previously described when both groups of finders are available. However, because there

is no B finder group available, the lock circuit to relay *U*4 is incomplete. Thus when relay *G*4 opens the circuits to relays *U*4, *L*4, *K*4, and *C*4, relay *U*4 will also restore.

When relay *U*4 restores, it completes the multiple circuits to relay *F*4 before it (relay *F*4) can restore as a result of its circuit being opened by the slow releasing of relay *C*4.

The circuit has been prepared to route the call to the next finder without operating the FINDER RESET KEY. The next finder in line now searches for the call because the defective finder has been bypassed.

FAILURE OF FINDER TO FIND NEGATIVE BATTERY (ELEVENTH ROTARY STEP KICKOFF).—In rotary hunting the finder hunts for the negative battery placed on the *C* contact of the calling party by relay *L*2. If a finder fails to find a line marked by negative battery for example because of insulated wiper contacts (relays *E*4, *T*4, *H*4, *K*4, *D*6, and *G*4 operated), it will step vertically until direct ground is encountered from relay *K*4 through the *L5AG* lead at the fifth level of the vertical banks. The finder will then take 10 rotary steps without encountering negative battery. On the eleventh rotary step, contacts 1–2 of the finder cam springs operate to place ground on the *G* lead to operate relay *B*4. This ground causes the control relays to operate, the distributor relays to allot the next finder to the call, and the first finder to restore. Thus an eleventh rotary step kick off condition results in the first finder being restored to normal and the next finder being allotted to the call.

Calls to a Station

When a station is called, the connector (not shown) places ground on the *CN* lead of the called bank contacts. Ground on the *CN* lead operates relay *L*2 completely. When relay *L*2 operates completely, it removes attachments from the line and opens the starting circuit to prevent false operation of a finder. Ground on the *CN* lead makes this line busy to all other calls.

Connection to a Shoreline Circuit

If the shorelines are to be used, the SHORELINE CONTROL SWITCH on the lamp and key panel is operated to complete the circuit to the *LT* (line transfer) relays (part 1B).

When the line transfer relay, *LT1B*, operates, it transfers the LINE and *CN* leads from the local station circuit to the two-way local trunk circuit in the attendant's cabinet. The calls from a trunk circuit operate the finder in a manner similar to that described for a normal call.

Executive Right-Of-Way Service

In stations that require executive right-of-way service, the *EC* lead of the finder is strapped to ground to cause the connector associated with the finder to cut in on a busy line.

Start and Level Marking Circuit

In the start and level marking circuit (part 3A), 10 line relays are common to any vertical bank contact of group A or group B finders. The first 50 lines are connected so that the first 10 lines have connections to the first vertical bank contact of all group A finders, but are not wired to group B finders. The second 10 lines have connections to the second vertical bank contact of group A finders and the ninth vertical bank contact of group B finders. The remainder of the first 50 lines are connected to both groups.

The second 50 lines are arranged so that the tenth group of 10 lines have connections to the first vertical bank contact of group B finders, but are not wired to group A finders. The ninth group of 10 lines have connections to the second vertical bank contact of group B finders and the ninth vertical bank contact of group A finders. The remainder of the last 50 lines are connected to both groups.

This method of making connection, as described earlier, allows one group of finders to search for the first 50 subscriber lines and the other group to search for the second

50 lines, with both searching normally over the first five levels. However, both groups of finders have access to the entire 100 lines under abnormal conditions.

When a finder operates, it normally places ground on the fifth level so that it cannot search above that level. When the partner group has an ATB (all trunks busy) condition, the fifth level mark is removed so that the other group can find all calls.

The "0" (zero) level is grounded in all cases so that the finder will always stop vertical motion when the tenth level is reached. With that level grounded, the finder will not continue to attempt vertical stepping when a line cannot be found.

All Finders Busy Circuit

When both groups of finders have an ATB condition, the *F*4 relays in both finder control groups will be restored. This action closes the *AFB* leads to complete a circuit to relay *FB*9 in the all finders busy circuit (part 9). The circuit is from *SJ*31 through contacts 1–2 of relay *F*4 (restored) over the *AFB* (out) lead, through contacts 1–2 of relay *F*4*A* (restored) group B, and to relay *FB*9 to negative battery.

RELAY *FB*9 OPERATES:

1. Contacts 1–2 remove direct ground from the *APB* lead to prevent any line relay from operating.
2. Contacts 2–3 complete a circuit to start the ringing machine through the *MST* lead.
3. Contacts 4–5 complete a circuit to extend the *AFB* (all finders busy) tone to the calling line through the induction coil.

If a call is now initiated, the AFB tone will indicate an ATB condition to the calling station. The induction coil, *FB*1 and *FB*2, is used to prevent the AFB tone from leaking into other circuits.

Line Disconnect Key Circuit

The line disconnect key circuit for local lines and for local and shorelines is illustrated in parts 1A and 1C respectively. If a line is to be disconnected, the LINE DISCONNECT KEY is operated to open the $-L$ and $+L$ lines from the telephone and to open the CN lead to the connector banks.

Simultaneous Calls

When several calls are originated simultaneously, before selection of finders and seizure has taken place for all of them, the finder operates until it finds the lowest vertical level marked for a call, and then rotates until it finds the first marked contact. After the controls are restored, a second finder starts and repeats this sequence of selection. Calls are selected in the order of their number assignment, as previously described in line grouping on finder banks. In group A, number 11 is the first telephone, followed by the remainder of the telephones connected to the first level; the other four vertical levels are in their order with telephone number 50 as the last telephone in that group. In group B, number 01 is the first telephone, followed by the remainder of the telephones connected to the first level; the other four vertical levels are in their order with telephone number 60 as the last telephone in that group.

Finder Blocked Key Circuit

When the FINDER BLOCKED KEY (part 4) of a finder control circuit is operated, the circuit is opened to relay $F4$ to cause all calls to be handled by the other group. The key is used also to open the circuit to relay $U4$ in the event of a call blocked kickoff (initial signal) to cause the finder control circuit to restore to normal.

Resistance-capacitance networks are connected to the rotary and vertical leads to prevent destructive sparking at the contacts of $A4$.

CONNECTOR BOARD

The equipment mounted on the front of the connector board (fig. 11–5) consists of the group A connector switches, the test line jack, and the terminal blocks as required. A space is provided for mounting the test set on the front of the board when the group A connectors are to be tested.

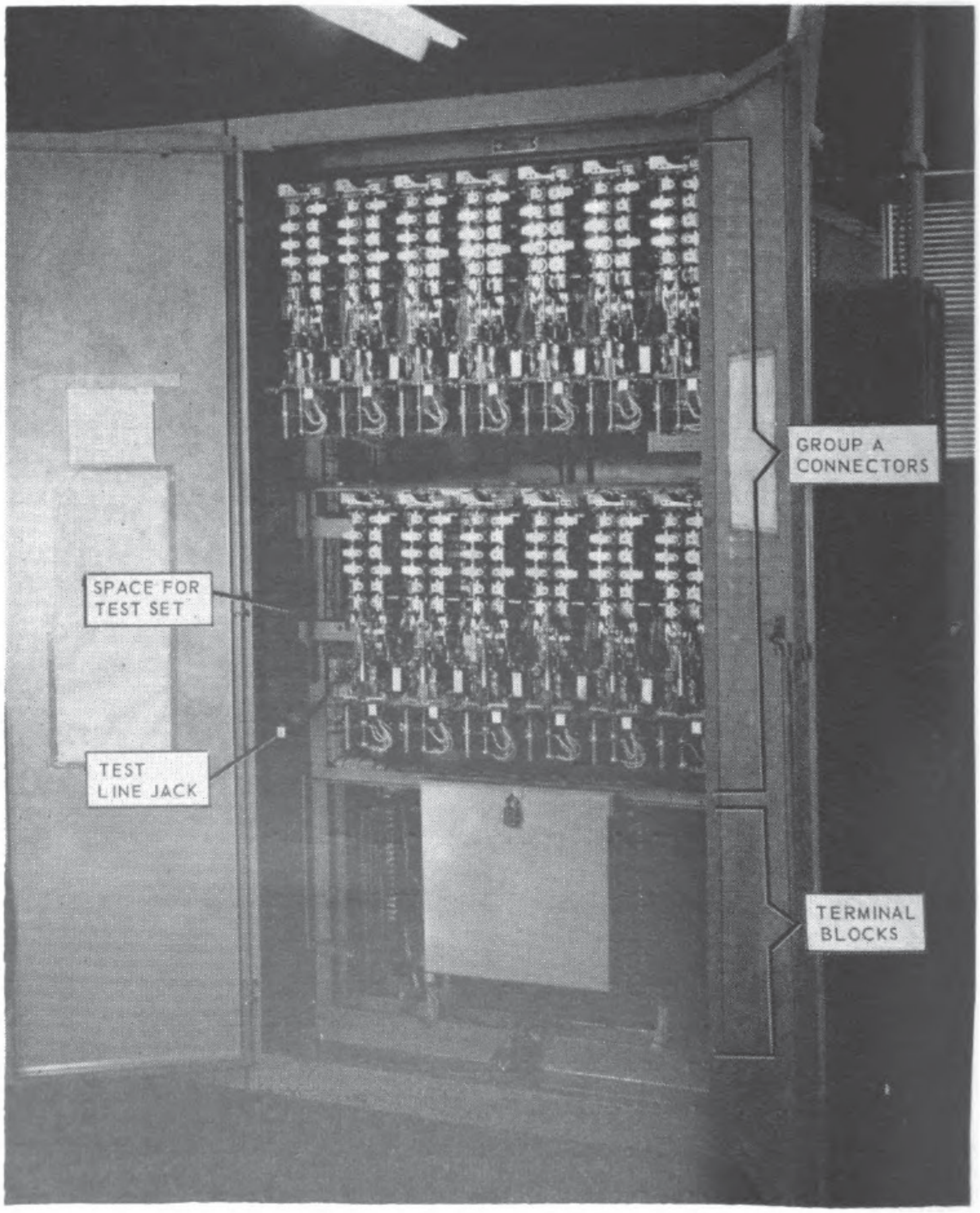


Figure 11—5.—Connector board (front).

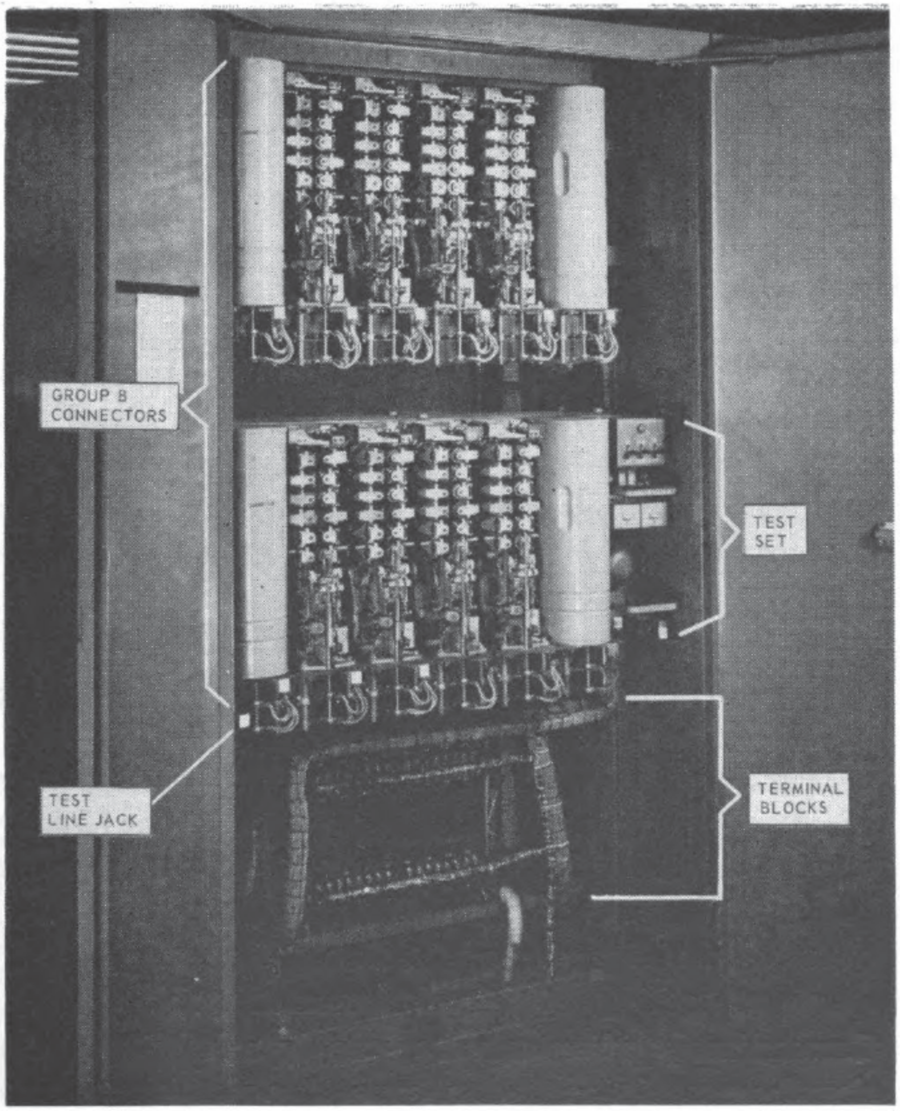


Figure 11—6.—Connector board (rear).

The equipment mounted on the rear of the connector board (fig. 11–6) consists of the group B connector switches, the test set, the test line jack, and the busy key (on the connector switch, not shown). The test set is described with the testing equipment in a separate chapter.

Connector Switch

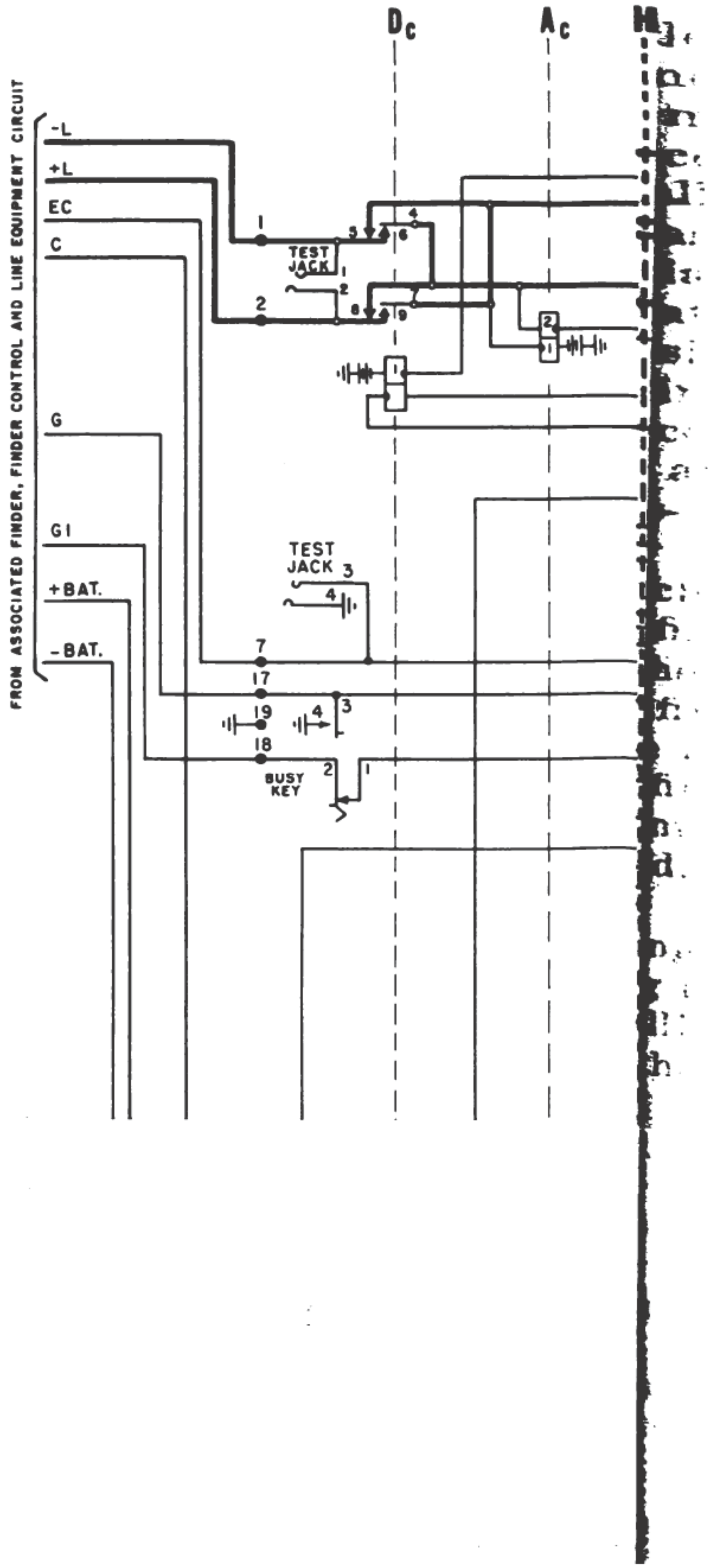
The connector switches, like the line finders, are 100-line Strowger switches. There are 25 connector switches, each connected directly to an associated line finder and

operated when the digits of a number are dialed. The shaft steps vertically on one series of impulses and rotates horizontally on another series of impulses to make the electrical connection between the phones. The connector switch completes the connection between the calling station and the called station, and controls the release of the connection. A connector switch and its associated line finder are called a LINK. The positive line, negative line, control line, *EC* lead, *G* lead, *G*1 lead, and the positive and negative battery (48 volts) are permanently wired from line finder 1 and connector 1 to comprise finder-connector link 1. The connectors on this switchboard are arranged to provide executive right-of-way and hunt-the-not-busy line services discussed previously.

Each connector is supplied with a minor switch to provide selective ringing of two-party lines. The first digit dialed will operate the minor switch to select the side of the line that is supplied ringing current. If the first digit dialed is 9, ringing current is supplied over the negative and positive sides of the line; whereas, if the first digit dialed is any digit other than 9, ringing current is supplied over the positive side of the line and ground.

The major functions of the connector are to:

1. Immediately after seizure, supply a holding circuit for the associated finder, cause the ringing machine to be started, connect dial tone to the calling line, make itself busy to other calls, and select the side of the line that is supplied ringing current.
2. Connect its wipers to the line number dialed and keep the circuit to the line wipers open while the wipers are being rotated over the bank contacts in response to impulses from the dial.
3. Test the called line to determine whether it is engaged or idle. If the line is found idle, to signal the called station and connect ring-back tone to the calling line. If the line is found busy, to give busy tone to the calling station.


FROM ASSOCIATED FINDER, FINDER CONTROL AND LINE EQUIPMENT CIRCUIT
-L
+L
EC
C
G
G1
+BAT.
-BAT.
TEST JACK
TEST JACK
BUSY KEY
Dc
Ac

PAGE NOT AVAILABLE

4. Complete the connection when the called party answers, remove ringing current from the calling and called lines, reverse battery on the calling line, and supply transmitter current to the calling and called stations.
5. Release when the calling party replaces the handset on the cradle switch, open the holding circuit to the associated finder switch, cause an alarm to be given if the switch does not return to normal within a predetermined interval of time after the release circuit has been completed, and open the starting circuit to the ringing machine control relays.
6. Hunt for a free line in a multiple-line group when the first line is busy, and give busy tone to a calling station when all lines are busy.
7. Act as an executive cut-in connector when the calling line is arranged for this service.

Test Line Jack

A test line jack is mounted on each side of the connector board. This jack provides access to the test line for testing purposes. It places ground on the *EC* lead, thereby providing connection for executive right-of-way service. It also provides connection directly to the + and — leads for dialing, talking, or monitoring.

Busy Key

The busy key on the connector switch places ground on the G lead to busy this connector switch and its associated line finder, and prepares the circuit to the next finder. It also opens the *G*1 lead to prepare the circuit to the ATB register.

CONNECTOR CIRCUIT OF FINDER-CONNECTOR LINK

The connector circuit of the finder-connector link (fig. 11–7) is used as a three-digit, group-hunting connector provided with executive right-of-way service.

The working names of the relays in the 100-line connector system are:

- A_c .... pulsing relay
- B_c .... link holding relay
- G_c .... first transfer relay (transfer from minor switch to vertical step of Strowger switch)
- C_c .... second transfer relay
- Z_c .... trouble relay
- E_c .... time delay relay
- H_c .... time delay relay
- M_c .... ring and ring-back put-on relay
- F_c .... ring and ring-back cutoff relay
- D_c ..... transmission battery for the called telephone (used to reverse transmission in telephones)
- K_c .... busy relay
- L_c .... executive right-of-way relay
- J_c .... trunk hunting relay

Also, the working names of switch jacks (SJ) and leads to the connector are:

- SJ5 .... negative battery and a-c component of ringing current switch jack
- SJ14 .... busy tone switch jack
- SJ15 ..... positive ground dial tone switch jack
- CP .... connector permanent lead
- CR SIG .... connector release signal lead

Functions

The connector circuit of the finder-connector link:

1. Place ground on the *C* wiper for busying all multipled bank contacts.
2. Steps the shaft in response to impulses sent out by the dial.
3. Provides first-digit selection of the side of the line for ringing.

4. Connects the + and − side of the line through to the called line.
5. Provides automatic group trunk hunting.
6. Provides part of a chain circuit to the ATB register.
7. Provides EXECUTIVE-RIGHT-OF-WAY service.
8. Guards its associated line finder during release.

This connector is arranged to be fused with its associated line finder.

Seizure

On both a commissioning call and a normal call the connector is preseized when the loop is completed to the L leads. The operating circuit or relay A_c is completed when relay $D6$ operates, closing its $4B$–$5B$ contacts. The circuit is from ground through contacts 5–6 of relay G_c, winding 2 of relay A_c to the $+L$ lead, contacts $4B$–$5B$ of relay $D6$ through winding 2 of relay $C6$ to the $-L$ lead to winding 1 of relay A_c to negative battery (fig. 11–7).

RELAY A_c OPERATES:

1. Contacts 1–2 open part of the impulsing circuit.
2. Contacts 2–3 complete a circuit to relay B_c.

RELAY B_c OPERATES:

1. Contacts 1–2 open the incomplete circuit to the *CR SIG* lead.
2. Contacts 2–3 complete ground to the C wiper through winding 1 of relay M_c.
3. Contacts 4–5 open part of the incomplete circuit to the Strowger (connector) *RLS* magnet and the minor switch *RLS* magnet in parallel.
4. Contacts 5–6 prepare a circuit through winding 1 of relay G to windings 2 of relays G_c and C_c.
5. Contacts 7–8 complete ground to the C lead, as previously mentioned, to make the calling line busy to further calls.
6. Contacts 9–10 complete a circuit to the C PERM lead to keep the ringing machine running after the finder controls restore.

7. Contacts 11–12 complete the operating circuits to relays G_c and C_c.

RELAY C_c OPERATES:

1. Contacts 1–2 open part of the incomplete impulsing circuit to the rotary magnets of the minor switch and to relays E_c and H_c.
2. Contacts 2–3 prepare a circuit to the vertical magnets and its own lock circuit.

RELAY G_c OPERATES:

1. Contacts 1–2 open part of the incomplete impulsing circuit to the vertical magnets of the minor switch and to winding 1 of relay C_c.
2. Contacts 2–3 prepare the impulsing circuit to the rotary magnets of the minor switch and to its own lock circuit.
3. Contacts 4–6 transfer the circuit through winding 2 of relay A from direct ground to ground on the DIAL TONE lead to prepare dial tone to the calling station and complete the first holding circuit to relay A_c.

As previously explained, relay $C6$ in the finder operates and completes the dial tone circuit from $SJ15$, through contacts 4–6 of relay G_c, through winding 2 of relay A_c, through contacts 8–9 of relay D_c, over the $+L$ lead, through contacts $5T$–$6T$ of relay $C6$, through the calling telephone, and back through the $-L$ lead, through contacts $7T$–$8T$ of relay $C6$ in the finder and through contacts 5–6 of relay D_c, to winding 1 of relay A_c to negative battery. Dial tone is now completed to the calling telephone and the first series of dialing can be started.

Dialing the Called Line

When the calling party dials the first digit (relays A_c, B_c, C_c, and G_c operated), the dialing loop is opened and completed to relay A_c by a series of impulses and pulses corresponding to the number dialed. Relay A_c restores and reoperates in response to the dial impulses and pulses.

RELAY A_c RESTORES:

1. Contacts 1–2 complete the lock circuit to relay G_c and complete the circuit to the minor switch rotary magnets.
2. Contacts 2–3 open the circuit to relay B_c.

Relay B_c does not restore during impulsing because of its slow-release characteristic.

MINOR SWITCH OPERATION (FIRST SERIES OF DIALING). —The minor switch (MS) rotary magnet operates (B_c, C_c, and G_c operated), and the switch steps to its first contact and operates the MSON springs.

MSON SPRINGS OPERATE:

1. Springs 1–2 complete the operating circuit to relay Z_c.
2. Springs 3–4 prepare part of an incomplete circuit to the MC RLS magnet.

RELAY A_c REOPERATES:

1. Contacts 1–2 open the circuit to relay G_c and the minor switch rotary magnets.
2. Contacts 2–3 complete the circuit to relay B_c.

Minor switch stops on a set of its contacts.

RELAY Z_c OPERATES:

1. Contacts 1–2 open the operating circuit to relay G_c.
2. Contacts 3–4 open an incomplete circuit to the *G*1 lead.
3. Contacts 4–5 complete ground to the *G* lead.
4. Contacts 6–7 prepare ground to the *CR SIG* lead.

Because of the slow-release characteristic of relay G_c, this relay remains operated until the last impulse of the first digit is completed.

When the second impulse of the first digit is received, relay A_c restores and sends out a second pulse to the MS magnet. Relay A_c then reoperates and awaits any additional impulses. Thus, each time relay A_c restores, the minor switch is stepped from one set of its contacts to the next adjacent set. This action continues until all of the first digit impulses have been received by relay A_c.

After the last impulse of the first digit has been completed, relay A_c reoperates and remains operated. Before the second digit is dialed, relay G_c restores.

RELAY G_c RESTORES:

1. Contacts 1–2 prepare a circuit to the (connector) vertical magnets and prepare the lock circuit to relay C_c.
2. Contacts 4–6 open the DIAL TONE lead from relay A_c.
3. Contacts 5–6 replace the operating ground to relay A_c.

VERTICAL STEPPING (SECOND SERIES OF DIALING).—When the calling party dials the second digit (A_c, B_c, C_c, Z_c, and the minor switch operated), the loop circuit is repeatedly opened, and completed to relay A_c. Relay A_c restores periodically in response to the dial impulses.

RELAY A_c RESTORES:

1. Contacts 1–2 complete the lock circuit to relay C_c and the operating circuit to the connector vertical magnets (Strowger switch).
2. Contacts 2–3 open the operating circuit to relay B_c. Relay B_c does not restore because of its slow-release characteristic.

The vertical magnets operate and raise the connector shaft vertically one step. This action operates the SVON springs.

SVON SPRINGS OPERATE:

1. Springs 1–2 prepare a circuit to the connector RLS magnet.
2. Springs 3–4 place a multiple ground and a hold on relay Z_c.
3. Springs 5–6 open the operating circuit of relay C_c.

Relay C_c remains operated until the last impulse of the second digit is completed because of its slow-release characteristic.

Relay A_c reoperates and remains operated after the last impulse of the second digit has been received.

RELAY C_c RESTORES:

1. Contacts 1–2 prepare a circuit to relays E_c and H_c and to the rotary magnets.
2. Contacts 4–5 prepare ground to the $G1$ lead.

ROTARY STEPPING (THIRD SERIES OF DIALING).—When the calling party dials the third digit (relays A_c, B_c, Z_c, the connector switch, and the minor switch operated), the loop circuit again is repeatedly opened to relay A_c. Relay A_c restores periodically in response to the dial impulses.

RELAY A_c RESTORES:

1. Contacts 1–2 complete the operating circuit to relays E_c, H_c, and the connector rotary magnets.
2. Contacts 2–3 open the circuit to relay B_c. However, relay B_c does not restore because of its slow-release characteristic.

RELAY E_c OPERATES:

1. Contacts 1–2 open an incomplete circuit to relay J_c.
2. Contacts 4–5 complete a hold circuit to relay H_c.
3. Contacts 6–7 complete a lock circuit to itself and to the rotary magnets and a hold on the connector rotary magnets.

RELAY H_c OPERATES:

1. Contacts 1–2 open an incomplete operating circuit to relay M_c.
2. Contacts 2–4 prepare a circuit from the C wiper to relay K_c in the event the called station is busy.
3. Contacts 5–6 open an incomplete circuit from the BUSY TONE lead to the calling party.
4. Contacts 7–8 open an incomplete circuit to relay L_c.

The connector rotary magnets operate and rotate the connector shaft one step. This action operates the SRON springs.

Relay E_c remains operated during the impulsing period because of its slow-release characteristic. When relay

A_c reoperates and remains operated after the last impulse of the third digit has been received, contacts 1–2 of relay A_c open the operating circuits of relay E_c and the rotary magnets.

SRON SPRINGS OPERATE:

1. Springs 1–2 further open the operating circuit to relay E_c and the connector rotary magnets to prevent further dialing.

RELAY E_c RESTORES:

1. Contacts 3–4 prepare an operating circuit to relay H_c.
2. Contacts 4–5 open an operating circuit to relay H_c.
3. Contacts 6–7 open its incomplete lock circuit.

Relay H_c does not restore immediately because of its slow-release characteristic.

Testing the Dialed Line (Third Series of Dialing)

DIALED LINE IDLE.—An idle station is marked with negative battery on the CN bank contact (A_c, B_c, Z_c, H_c, MS, SVON, SRON, and MSON operated). This negative battery prepares a circuit to relay M_c via the C wiper. Relay H_c is still operated because of its slow-release characteristic.

RELAY H_c RESTORES:

1. Contacts 1–2 complete the partial operating circuit to relay M_c and the operating circuit to the line relay $L2$ of the called telephone. Ground for these two circuits originates through contacts 2–3 of relay B_c.
2. Contacts 2–4 open an incomplete circuit to relay K_c.

RELAY M_c OPERATES PARTIALLY:

1. Contacts $1T$–$2T$ complete its operating and lock circuits. Ground is originated through contacts 11–12 of relay B_c (operated).

RELAY M_c OPERATES COMPLETELY:

1. Contacts $5T$–$6T$ complete ground to the C wiper to hold the called line relay and make this station busy.
2. Contacts $7T$–$8T$ and $8B$–$9B$ complete the ringing circuit from the *INT GEN* lead to the called station.
3. Contacts $1B$–$2B$ open the incomplete circuits to the RLS magnets.
4. Contacts $4B$–$5B$ complete the ring-back tone to the calling party through cutdown capacitor, A. The circuit is from the *INT GEN* lead, winding 1 of relay F_c, contacts 9–10 of relay F_c, contacts $4B$–$5B$ of relay M_c, through capacitor A, winding 2 of relay D_c, contacts $1B$–$2B$ of relay L_c, the line capacitor, P, and the $+L$ lead to the calling station.
5. Contacts $6B$–$7B$ prepare the operating circuit to relays F_c and D_c.

The called telephone is now ringing and when the called party answers by removing the receiver the partial operating circuit is completed to relay F_c through the hookswitch. When relay F_c operates partially, contacts 1–2 complete its full operating and lock circuits. (Ground for these circuits originates through contacts $6B$–$7B$ of relay M_c.) When relay F_c operates fully and locks, contacts 9–10 remove ring-back to the calling party and contacts 3–4 and 6–7 open the ringing circuit to the calling telephone. Also contacts 4–5 and 7–8 of relay F_c complete the operating circuit to relay D_c to reverse transmission battery and complete the talking circuit.

DIALED LINE BUSY.—If the called line is busy (A_c, B_c, Z_c, H_c, MS, MSON, SVON, and SRON operated), ground will be encountered by the C wiper when it moves onto the bank contacts of the called line. This wiper completes the operating circuit to relay K_c. It is important to remember that busy relay K_c only prepares and does not complete any circuits.

RELAY K_c OPERATES:

1. Contacts 1–2 prevent relay M_c from operating partially.
2. Contacts 3–4 prepare a circuit from the BUSY TONE lead to the calling party.
3. Contacts 7–8 prepare part of the circuit from the EC lead from the associated finder circuit to relay L_c.

RELAY H_c RESTORES:

1. Contacts 3–4 complete the lock circuit to relay K_c.
2. Contacts 2–4 open the operating circuit to relay K_c.
3. Contacts 5–6 complete the circuit from the BUSY TONE lead to the calling party.

Ringing the Dialed Station

The side of the line that is supplied ringing current is determined by the contacts on which the minor switch steps; that is, it depends on the first digit dialed. If the first digit dialed is 9, ringing current will be supplied over the — wiper of the connector switch by way of the top wafer of the minor switch returning over the + wiper. On the other hand, if the first digit dialed is any other than 9, ringing current will be supplied to the + wiper of the connector switch by way of the bottom wafer of the minor switch returning directly to ground. These circuits are described in detail in the following paragraphs.

When the line has been dialed and found free (relays A_c, B_c, E_c, H_c, and Z_c and MS, MSON, SVON, and SRON operated), relay H_c in the connector restores. This action completes a circuit to the called line relay, $L2$, in series with the ring and ring-back put-on relay, M_c. The called line relay operates completely to remove any line attachments. Relay M_c operates partially to complete its full operating circuit. Relay M_c operates completely to supply ringing and ring-back current.

Operation of the ringer on the dialed line signals the called party. The ringing circuit corresponding to any

first digit dialed other than 9 is from the *INT GEN* lead, through winding 1 of relay F, through the bottom minor switch wafer contact C and any other than contact 9, contacts 6–7 of relay F_c, contacts $7T$–$8T$ of relay M_c, to the + wiper, out to the called telephone ringer, and back in through the ground lead (not shown in the figure). This condition is called GROUND, or POSITIVE RING.

The ringing circuit corresponding to a first dialed digit of 9 is from the *INT GEN* lead, through winding 1 of relay F_c, through the top minor switch wafer contacts 9 and C, contacts 3–4 of relay F_c, contacts $8B$–$9B$ of relay M_c, to the — wiper, out to the called telephone ringer, back to the + wiper, to contacts $7T$–$8T$ of relay M_c, contacts 6–7 of relay F_c, to the bottom wafer contacts C and 9, and back through contacts $6B$–$7B$ of relay M_c, to ground. This condition is called METALLIC, or NEGATIVE RING.

The ringing current does not operate relay F_c. However, when the called party answers, the circuit is completed to relay F_c.

Dialed Station Answering

When the called party answers, the hook switch disconnects the ringer and completes a d-c circuit between $L1$ and $L2$ of the called station to increase the current through winding 1 of relay F_c. Relay F_c operates partially to close its X contacts (1–2) and to complete its operating circuit.

RELAY F_c OPERATES PARTIALLY:

1. Contacts 1–2 complete its operating and lock circuits.

RELAY F_c OPERATES PARTIALLY:

1. Contacts 3–4 and 6–7 remove ringing from the called telephone.
2. Contacts 4–5 and 7–8 complete the operating circuit to relay D_c. The circuit is from ground, through contacts $6B$–$7B$ of relay M_c, contacts 1–2 of relay F_c, winding 2 of relay D_c, contacts 7–8 of relay F_c, contacts $7T$–$8T$ of relay M_c, through the

d-c loop of the called telephone, contacts 4–5 of relay F_c, winding 1 of relay D_c, and negative battery.

3. Contacts 9–10 open the circuit of capacitor *A* to remove ring-back tone from the calling telephone.

RELAY D_c OPERATES:

1. Contacts 2–3 complete an additional (second) lock circuit to relay *C*6 (fig. 11–4) and the third lock circuit to the calling line relay.
2. Contacts 4–6 and 7–9 complete a circuit to relay A_c and reverse transmission battery to the calling station by placing ground on the *C* lead.

Transmission

Transmission (talking) battery is supplied to the calling and called parties through relays A_c and D_c respectively.

Release

CALLING PARTY RELEASES FIRST.—When the calling party hangs up the receiver (A_c, B_c, Z_c, MS, MSON, SVON, SRON, M_c, F_c and D_c operated), the loop circuit is open to relay A_c.

RELAY A_c RESTORES:

1. Contacts 1–2 prepare part of the circuit to both the minor-switch and connector-switch RLS magnets.
2. Contacts 2–3 open the circuit to relay B_c.

RELAY B_c RESTORES:

1. Contacts 1–2 complete the circuit to the *CR SIG* lead to provide connector release supervision.
2. Contacts 2–3 open the partial operating circuit through winding 1 of relay M_c.
3. Contacts 4–5 prepare a circuit to the connector and minor-switch RLS magnets.
4. Contacts 7–8 remove a multiple ground from the *C* lead.
5. Contacts 9–10 open the incomplete circuit to the *C* PERM lead.

6. Contacts 11–12 open the full operating and lock circuits to relay M_c.

RELAY M_c RESTORES:

1. Contacts $5T$–$6T$ remove ground from the C wiper, which in turn removes the hold circuit from the called line relay, causing this relay to restore partially. Before interruption, the circuit of the called line relay was from ground, through contacts $5T$–$6T$ of relay M_c, the C wiper over the CN lead to the line disconnect key, the $CN1$ lead to winding 1 of the called line relay, to negative battery. The called line relay is not shown in the figure, but is similar to relay $L2$ in figure 11–4.
2. Contacts $7T$–$8T$ and $8B$–$9B$ open the transmission (talking) circuit to the called station.
3. Contacts $1B$–$2B$ complete the circuit to the connector and minor-switch RLS magnets.
4. Contacts $6B$–$7B$ open the operating circuit to relays F_c and D_c.

When relay F_c restores, no action occurs.

RELAY D_c RESTORES:

1. Contacts 2–3 open the third lock circuit to the calling line relay $L2$ and the second lock circuit to relay $C6$ (fig. 11–4). The d-c loop of the calling telephone to relay $L2$ was opened when the calling party hung up. Thus $L2$ restores completely.

The connector-RLS magnet operates and restores the connector-switch shaft to normal. This action causes the connector-rotary and vertical off-normal springs to assume their normal positions.

SVON SPRINGS RESTORE:

1. Springs 1–2 open the circuit to the connector-RLS magnet.
2. Springs 3–4 open the holding circuit of relay Z_c.

The connector RLS magnet restores.

MINOR-SWITCH RLS MAGNET OPERATES: (The circuit is completed from ground, to contacts 1–2 of relay A_c, con-

tacts 4–5 of relay B_c, contacts 1B–2B of relay M_c, the MSON springs 3–4, to winding 1 of the minor-switch release magnet, to negative battery.)

1. Restores the minor-switch wipers to normal.
2. Restores the MSON springs to normal.

MSON SPRINGS RESTORE:

1. Springs 1–2 open the operating circuit to relay Z_c.
2. Springs 3–4 open the circuit to the minor-switch RLS magnet.

The minor-switch RLS magnet restores.

RELAY Z_c RESTORES:

1. Contacts 3–4 place ground on the $G1$ lead.
2. Contacts 4–5 remove ground from the G lead.

The connector is now at normal.

RELAY $C6$ RESTORES (fig. 11–4):

1. Contacts $1B$–$2B$ complete the operating circuit to the finder-release magnet.

FINDER RLM OPERATES:

1. Springs 1–2 complete a circuit on the FR SIG lead to provide finder release supervision.

The finder switch restores to normal and restores the VON springs.

VON SPRINGS RESTORE:

1. Springs 1–2 open the circuit to the finder RLS magnets.

FINDER-RLS MAGNETS RESTORE:

1. Springs 1–2 open the circuit on the FR lead.

The finder is now at normal.

CALLED PARTY RELEASES FIRST.—When the called party hangs up the receiver (A_c, B_c, Z_c, MS, MSON, SVON, SRON, M_c, F_c, and D_c operated), the circuit is opened to relay D_c.

The circuit to relay D_c that is interrupted by the hook switch extends from negative battery, winding 1 of relay D_c, contacts 4–5 of relay F_c, contacts $8B$–$9B$ of relay M_c, the called line, contacts $7T$–$8T$ of relay M_c, contacts 7–8 of relay F_c, winding 2 of relay D_c, contacts 1–2 of relay F_c, contacts $6B$–$7B$ of relay M_c, to ground.

RELAY D_c RESTORES:

1. Contacts 1–2 complete a circuit to the *C* PERM lead.
2. Contacts 2–3 remove ground from the *C* lead. From this point on, the release is under the control of the calling party. Until the calling party releases, the connector will remain operated. When the calling party hangs up the receiver, the loop circuit is opened to relay A_c.

RELAY A_c RESTORES:

1. Contacts 2–3 open the operating circuit to relay B_c.

RELAY B_c RESTORES:

1. Contacts 1–2 complete the circuit to the *CR SIG* lead to provide connector release supervision.
2. Contacts 2–3 open the circuit through winding 1 of relay M_c.
3. Contacts 4–5 prepare a circuit to the connector and minor switch RLS magnets.
4. Contacts 7–8 remove the ground from the *C* lead and relay *C*6 (fig. 11–4), and the calling line relay will restore.
5. Contacts 9–10 open the circuit to the *C* PERM lead.
6. Contacts 11–12 open the lock circuit to relay M_c.

RELAY M_c RESTORES:

1. Contacts 5*T*–6*T* remove ground from the *C* wiper, and the called line relay restores completely. (The d-c loop through the hook switch of the called telephone is open so that windings 2 and 3 are not energized.)
2. Contacts 7*T*–8*T* and 8*B*–9*B* open the transmission circuit to the called station.
3. Contacts 1*B*–2*B* complete the circuit to the connector and minor-switch RLS magnets.
4. Contacts 6*B*–7*B* open the lock circuit to relay F_c.

When relay F_c restores, no action occurs.

The connector-RLS magnet operates and restores the connector-switch shaft to normal. This action causes the connector-rotary and vertical off-normal springs to assume their normal positions.

SVON SPRINGS RESTORE:

1. Springs 1–2 open the circuit to the connector RLS magnet.
2. Springs 3–4 open the holding circuit of relay Z_c.

The connector-RLS magnet restores.

MINOR-SWITCH RLS MAGNET OPERATES:

1. Restores the minor-switch wipers to normal.
2. Restores the MSON springs to normal.

MSON SPRINGS RESTORE:

1. Springs 1–2 open the circuit to relay Z_c.
2. Springs 3–4 open the circuit to the minor-switch RLS magnet.

The minor-switch RLS magnet restores.

RELAY Z_c RESTORES:

1. Contacts 3–4 place ground on the *G*1 lead.
2. Contacts 4–5 remove ground from the *G* lead.

The connector is now at normal.

When the calling line relay releases, no action occurs.

RELAY *C*6 (fig. 11–4) RESTORES:

1. Contacts 1*B*–2*B* complete the operating circuit to the finder release magnets.

FINDER RLM OPERATES:

1. Springs 1–2 complete a circuit on the FR SIG lead to provide finder release supervision.
2. The finder switch restores to normal. VON springs restore:
   1. Springs 1–2 open the circuit to the RLS magnets.

RLS MAGNETS RESTORE:

1. Springs 1–2 open the circuit on the FR lead.

The finder is now at normal.

RELEASE FROM A BUSY CONDITION.—When a calling party receives the BUSY TONE and hangs up the receiver (A_c, B_c,

Z_c, K_c, MS, MSON, SVON, and SRON operated), the d-c loop circuit is opened to relay A_c.

RELAY A_c RESTORES:

1. Contacts 1–2 prepare the circuit to the connector switch and minor-switch RLS magnets.
2. Contacts 2–3 open the circuit to relay B_c.

RELAY B_c RESTORES:

1. Contacts 2–3 open the first lock circuit to relay K_c through contacts $6T$–$7T$ of relay L_c, contacts 9–10 of relay K_c, contacts 3–4 of relay H_c, winding 1 of relay K_c, and negative battery.
2. Contacts 4–5 complete the operating circuit to the connector-switch RLS magnets and the minor-switch RLS magnets.
3. Contacts 7–8 remove ground from the C lead and relay $C6$ (fig. 11–4), and the calling line relay will restore. When relay $L2$ restores, no action occurs.
4. Contacts 9–10 open the circuit to the C PERM lead.

Relay K_c restores and no action occurs.

The connector-RLS magnet operates and restores the connector-switch shaft to normal. This action causes the connector-rotary and vertical off-normal springs to assume their normal positions.

SVON SPRINGS RESTORE:

1. Springs 1–2 open the circuit to the connector-RLS magnet.
2. Springs 3–4 open the holding circuit of relay Z_c.

The connector-RLS magnet restores.

MINOR-SWITCH RLS MAGNET OPERATES:

1. Restores the minor-switch wipers to normal.
2. Restores the MSON springs to normal.

MSON SPRINGS RESTORE:

1. Springs 1–2 open the operating circuit to relay Z_c.
2. Springs 3–4 open the circuit to the minor-switch RLS magnet.

The minor-switch RLS magnet restores.

RELAY Z_c RESTORES:

1. Contacts 3–4 place ground on the *G*1 lead.
2. Contacts 4–5 remove ground from the *G* lead.

The connector is now at normal.

RELAY *C*6 (fig. 11–4) RESTORES:

1. Contacts 1*B*–2*B* complete the operating circuit to the finder-RLS magnet.

FINDER-RLS MAGNET OPERATES:

1. Springs 1–2 complete a circuit on the FR SIG lead to provide finder-release supervision.

The finder switch restores to normal and restores the VON springs.

FINDER VON SPRINGS RESTORE:

1. Springs 1–2 open the circuit to the finder RLS magnets.

FINDER-RLS MAGNETS RESTORE:

1. Springs 1–2 open the circuit on the *FR SIG* lead.

The finder is now at normal.

Executive Right-of-Way Service

Executive right-of-way service is accomplished by the presence of positive ground on the *EC* lead. Usually, the *C* and *EC* leads are strapped together at the finder bank terminal strip to obtain this service. The positive ground originates through contacts 7–8 of relay B_c (operated) that is used by the executive telephone and extends over the C lead to the finder bank terminal strip, back over the *EC* lead, to contacts 7–8 of relay K_c. This ground is only used when the executive telephone cuts in on a busy called station.

DIALED LINE IDLE.—When the dialed line is idle, the functions of seizure, dialing, testing, ringing, connecting, and transmission to the dialed line are similar to the previously explained corresponding functions, except that ground is placed on the EC lead upon seizure but is never used.

DIALED LINE BUSY.—When the dialed line is busy (A_c, B_c, Z_c, K_c, MS, MSON, SVON, and SRON operated), the functions of seizure and dialing are similar to the previously explained corresponding functions, except that relay K_c will operate when the C wiper of the connector encounters positive ground from the busy station. Positive ground will be encountered by the C wiper when it moves onto the bank contacts of the called line. This ground completes the circuit to relay K_c. When relay A_c restores after the last digit impulse is received, relay E_c restores, thereby restoring relay H_c. Contacts 7–8 of relay H_c (restored) complete the operating circuit to the executive relay, L_c, from ground on the EC lead, which is strapped to the C lead for executive right-of-way service.

RELAY L_c OPERATES:

1. Contacts $2B$–$3B$ and $5B$–$6B$ connect the talking circuit through to the called party.
2. Contacts $1T$–$2T$ open the circuit to the BUSY TONE lead so that the executive telephone does not hear busy tone when cutting in on a busy telephone.
3. Contacts $3T$–$4T$ short-circuit winding 2 of relay K_c, making it slow to release.
4. Contacts $5T$–$7T$ complete another circuit to relay K_c through contacts 9–10 of relay K_c and contacts 3–4 of relay H_c.
5. Contacts $7B$–$8B$ complete its lock circuit.

The executive telephone can (1) cut in, (2) talk, and (3) hang up or talk privately with the station dialed by telling both parties to hang up. This action causes the finder-connector link to release and remove the busy ground. It also permits relay K_c to restore and complete a partial circuit to relay M_c in series with the called line relay.

RELAY K_c RESTORES:

1. Contacts 7–8 open the operating circuit of relay L_c.

2. Contacts 1–2 complete the circuit from contacts 2–3 of relay B_c to the called line relay through winding 1 of relay M_c.

RELAY M_c OPERATES PARTIALLY:

1. Contacts $1T$–$2T$ complete its operating and lock circuits.

RELAY M_c OPERATES COMPLETELY:

1. Contacts $3T$–$4T$ further open the circuit to relay L_c.
2. Contacts $5T$–$6T$ complete ground to the C wiper to hold the calling line relay.
3. Contacts $7T$–$8T$ complete the circuit from the *INT GEN* lead to the + wiper.
4. Contacts $8B$–$9B$ place ground on the − wiper through contacts 3–4 of relay F_c, the top of the minor switch, and contacts $6B$–$7B$ of relay M_c to ground.
5. Contacts $1B$–$2B$ open the incomplete circuits to the RLS magnets.
6. Contacts $6B$–$7B$ prepare the operating circuit to relays F_c and D_c.

RELAY L_c RESTORES:

1. Contacts $1B$–$2B$ complete ring-back tone to the calling executive telephone from the + wiper through capacitor P to the + L lead.

The station dialed by the executive telephone will ring and the executive telephone will hear the ring-back tone. When the call is answered, the connection will be completed to relay F_c and normal relay operation occurs.

Transmission and releasing are normal, as previously described for these functions.

Hunt-the-Not-Busy-Line Service (Trunk Hunting)

As previously described at the beginning of this chapter, certain important stations have two or more telephones wired with a special feature known as hunt-the-not-busy-line service, which is commonly called trunk hunting. This arrangement allows the calling telephone

on dialing the lower number in a hunt-the-not-busy-line group to get a free telephone if there is a free telephone in that group. Trunk hunting is accomplished by automatically giving the rotary magnets of the connector an extra operating circuit when the lower numbered telephone is busy.

A trunk hunting group consists of several telephones so selected in the connector banks that their lines terminate on the same level and the telephones are arranged in numerical sequence. The trunk hunting feature is provided at the connector bank terminal strip by strapping together the CN and ECN terminals of all but the last telephone in the trunk hunting group. Hence, in order to make a group of telephones trunk hunting: (1) the lines of the selected telephones must terminate on the same bank level; (2) the selected telephone must be in numerical sequence; (3) the CN and ECN leads of all except the last telephone must be strapped together at the connector bank terminal strip; and (4) the last telephone in the group is not trunk hunting (busy tone is completed if the last telephone is busy).

If the first telephone of the group is busy, the *C* wiper encounters positive battery on the *C* contact and completes the operating circuit to the busy relay, K_c. Because the *CN* and *ECN* contacts are connected together, the *EC* wiper also encounters positive ground and prepares an operating circuit to the trunk hunting relay, J_c. The operating circuit to relay J_c will be completed when relay E_c restores after the third series of dialing. When any group trunk except the last one is busy, ground from the *CN* bank contact is on the *ECN* bank contact. When the wipers are stepped to a group trunk that is busy, ground on the *CN* and *ECN* bank contacts is transferred to the *C* and *EC* wipers, and relay K_c will operate. Relay H_c remains operated until either a free telephone is found or until the wipers step rotary to the last station of the group, at this time relay H_c will restore to complete busy tone.

TESTING THE DIALED GROUP OF TRUNKS (THIRD SERIES OF DIALING).—The functions of seizure and dialing on a call to a trunk hunting group are the same as those for a normal call, except for the third series of dialing.

Assume that only the first station of the trunk hunting group to be busy (A_c, B_c, E_c, H_c, Z_c, MS, MSON, SVON, and SRON operated). The C wiper encounters busy ground.

RELAY K_c OPERATES:

1. This relay only prepares circuits in operating.

After the third series of dialing, relay E_c restores.

RELAY E_c RESTORES:

1. Contacts 1–2 complete the operating circuit of relay J_c.
2. Contacts 3–4 prepare the second hold circuit to relay H_c.
3. Contacts 4–5 open the first hold circuit to relay H_c.

RELAY J_c OPERATES:

1. Contacts 1–2 complete its own lock circuit.
2. Contacts 3–4 complete the second hold circuit to relay H_c and an operating circuit to the rotary magnets.

ROTARY MAGNETS OPERATE:

1. Step the wipers to the next trunk in the group.
2. Interrupter springs 1–2 open the operating circuit to relay J_c.

RELAY J_c RESTORES:

1. Contacts 1–2 open its lock circuit.
2. Contacts 3–4 open the circuits to relay H_c and to the rotary magnets.

ROTARY MAGNETS RESTORE:

1. Interrupter springs 1–2 complete the operating circuit to relay J_c. However, relay J_c does not reoperate because this station is free and there is no busy ground on the *EC* contact.

RELAY K_c RESTORES:

1. Contacts 1–2 prepare the partial operating circuit to relay M_c.

RELAY H_c RESTORES:

1. Contacts 1–2 complete the partial operating circuit to relay M_c, and the full operating circuit to the called line relay.

RELAY $L2$ OPERATES (CALLED):

1. Contacts 5–6, 7–8, and 9–10 open. This action prevents the called station from starting the control relays and stepping a finder.

RELAY M_c OPERATES PARTIALLY:

1. Contacts $1T$–$2T$ complete its own operating and lock circuits.

RELAY M_c OPERATES FULLY:

1. Contacts $5T$–$6T$ complete the hold circuit to the called line relay (busy ground for the called telephone).
2. Contacts $7T$–$8T$ and $8B$–$9B$ complete the ring circuit to the called station.
3. Contacts $4B$–$5B$ complete the ring-back circuit to the calling station.
4. Contacts $6B$–$7B$ prepare the operating circuit to relay F_c.

The functions of finding, connecting through, and ringing the first idle telephone in the called trunk hunting group are completed. The corresponding functions of transmission and release are the same as those previously described for a normal call.

In the foregoing circuit analysis, only the first telephone in the trunk hunting group was assumed to be busy. However, if the next trunk is also busy, the circuit will again operate, as previously described. If all the trunks are busy, the wipers will be stepped to the last trunk. The absence of positive ground on the ECN bank contact (because the last telephone in the group is not trunk hunting and the *CN* and the *ECN* leads are not strapped together) prevents an additional operating circuit to relay J_c. Relay J_c will restore and open the circuit to the rotary magnets and to relay H_c.

RELAY H_c RESTORES:

1. Contacts 3–4 complete a lock circuit to relay K_c.
2. Contacts 5–6 complete busy tone.

QUIZ

1. Name the five types of services provided by the 100-line dial telephone system.
2. What are the functions of each of the three-digit numbers assigned to the telephones in the 100-line system aboard ship?
3. If the first digit dialed is any digit other than 9, which side of the line will ringing current be supplied over?
4. If the first digit dialed is 9, over which side of the line will ringing current be supplied?
5. Name the two boards that comprise the automatic switchboard.
6. What double purpose does a line relay serve?
7. In how many steps does a line relay operate?
8. On outgoing calls from a telephone line when the handset is removed from the cradle: (a) To what step does the line relay operate? (b) How does this action affect the operation of the line-finder equipment?
9. On outgoing calls from a telephone line: (a) To what step does the line relay operate when a finder switch connects with the line? (b) How does this action affect the connection of the line relay windings with respect to the telephone line?
10. On incoming calls to a telephone line: (a) To what step does the line relay operate when the connector switch operates? (b) How does this action affect the connection of the line relay windings with respect to the telephone line? (c) Why?
11. How many finder switches are provided in the 100-line dial telephone system?
12. Name the two principal functions of the finder switch.
13. What equipment controls the operations of the finder switch?
14. How many finder switches are in the (a) A group and (b) B group?
15. How many telephones are normally served by (a) the group A finders and (b) the group B finders?
16. What action occurs in the group B finders if a call is originated on a particular line in group A when all the finders in this group are busy?

17. What is the function of the finder control relays associated with each group of finders?
18. What is the function of the distributor relays associated with each group of finders?
19. What type of fuse is contained on the fuse panel for the protection of the switchboard equipment?
20. Name the two types of calls encountered in this telephone system.

REFERRING TO FIGURE 11–4 FOR QUESTIONS 21 THROUGH 66:

21. What action completes the partial operating circuit to relay $L2$ on a commissioning call?
22. Where does ground originate to operate relay $F4$ on a commissioning call?
23. Where does ground originate to operate relay $E4$ on a commissioning call?
24. What completes the operating circuit to relays $G4$ and $T4$ on a commissioning call?
25. What completes the operating circuit to relay $E4$ on a normal call?
26. What completes the operating circuit to relay $T4$ on a normal call?
27. What completes the lock circuit of relay $G4$ on a normal call?
28. Where does ground originate to operate relay $G4$ on a normal call?
29. Where does ground originate to operate the vertical magnets on a normal call?
30. Where does ground originate to operate relay $D6$ on a normal call?
31. What completes the operating circuit to relay A_c (fig. 11–7) in the connector on a normal call?
32. What completes the first holding circuit or relay A_c in the connector on a normal call?
33. What transfers the vertical stepping circuit to the rotary stepping circuit on a normal call?
34. What completes the operating circuit to relay $J4$ on a normal call?
35. What completes the operating and first lock circuits to relay $L2$ on a normal call?

36. What transfers the rotary stepping circuit to relay *C*6 on a normal call?

37. What completes dial tone on a normal call?

38. What completes the operating circuit to relay *B*4 on a normal call?

39. Where does ground originate for the second holding circuit of relay A_c in the connector on a normal call?

40. Where does ground originate for the first lock circuit of relay *C*6 on a normal call?

41. Where does ground originate for the second lock circuit of relay *L*2 on a normal call?

42. In selecting the first idle finder, what completes the operating circuit to the (next) *FD*2 relay in the chain?

43. In selecting the next idle finder, what prepares the operating circuit to the (next) *FD*3 relay in the chain?

44. In selecting the next idle finder, what opens the operating circuit of the FST lead to relay *D*6?

45. In selecting the next idle finder, what prepares a circuit to relay *RS*2*A*?

46. What prevents a busy finder from being seized for another call?

47. What prepares a lock circuit to relay *FD*1 when relay *FD*13 is energized?

48. What completes the circuit to the release magnet when the calling party hangs up?

49. In an ATB condition, what is the holding circuit for relay *F*4 when the last free finder begins to search for a line?

50. In an ATB condition, what transfers the calls from group A to group B controls when the calling line has been located and the finder controls have been released?

51. In an ATB condition, what makes it possible for group B finders to search for all calls when all group A finders are busy?

52. In an ATB condition, what makes it possible for the group B finders to search above the fifth level?

53. In an ATB condition, when is ground placed on the ATBG lead of the group A finders?

54. What four relays are operated only during a call-blocked kickoff condition?

55. How long does it take for a call-block kickoff condition to occur if relay $B4$ does not operate when a normal call is initiated?

56. What completes the operating circuit to the next FD relay ($FD4$ in this case) in a call-blocked kickoff?

57. What completes the shunt to relay $C4$ in a call-blocked kickoff?

58. What opens the operating circuit to the next FD relay ($FD4$ in this case) on a call-blocked kickoff?

59. What opens the second holding circuit of relay $F4$ on a call-blocked kickoff?

60. What is the purpose of the finder reset key?

61. What causes an eleventh rotary step kickoff?

62. Where does ground originate to operate relay $B4$ on an eleventh rotary step kickoff?

63. How many line relays are common to any vertical bank contact of group A or group B finders?

64. What completes the operating circuit to relay $FB9$ when both groups of finders have an ATB condition?

65. What completes AFB (all finders busy) tone to the calling line?

66. What is the purpose of the $FB1$ and $FB2$ induction coil?

67. What is the function of the connector switch?

68. What is a connector switch and its associated line finder called?

69. What is the purpose of a minor switch?

REFERRING TO FIGURE 11–7 FOR QUESTIONS 70 THROUGH 126:

70. What completes the operating circuit to relay A_c?

71. What completes the first holding circuit of relay A_c?

72. What relays are operated in the connector when it is preseized?

73. What completes the lock circuit to relay G_c on the first series of dialing?

74. What completes the operating circuit to relay Z_c on the first series of dialing?

75. What opens the operating circuit to relay G_c?

76. What removes dial tone on the first series of dialing?

77. What completes the operating circuit to the connector switch vertical magnets on the second series of dialing?

78. What opens the operating circuit of relay C_c on the second series of dialing?

79. What completes the operating circuits to relays E_c, H_c, and the connector rotary magnets (Strowger switch) on the third series of dialing?

80. What completes the hold circuit to relay H_c on the third series of dialing?

81. What completes the partial operating circuit to relay M_c on the third series of dialing?

82. Where does ground originate to partially operate relay M_c and to operate (fully) relay $L2$ of the called telephone on the third series of dialing?

83. What completes the full operating and lock circuits to relay M_c on the third series of dialing?

84. What completes the ringing circuit to the called telephone on the third series of dialing?

85. What completes ring-back to the calling party on the third series of dialing?

86. Where does ground originate for the operating and lock circuits of relay F_c on the third series of dialing?

87. What completes the operating circuit to relay K_c when the dialed line is busy on the third series of dialing?

88. What completes the busy tone circuit when the dialed line is busy on the third series of dialing?

89. How is the called line, relay $L2$, connected with respect to the ring and ring-back put-on relay, M^c, when ringing the dialed station?

90. What first digits may be dialed to obtain ground or positive ring?

91. What first digit is dialed to obtain metallic or negative ring?

92. What completes the operating circuit of relay F_c when the dialed station answers?

93. What removes ringing from the called telephone?

94. What completes the operating circuit to relay D_c when the dialed station answers?

95. What removes ring-back from the calling telephone when the dialed station answers?

96. What completes the second lock circuit to relay *C6* (fig. 11–4) and the third lock circuit to the calling line relay when the dialed station answers?

97. What reverses transmission battery to the calling station when the dialed station answers?

98. When is the loop opened to relay A_c?

99. What opens the partial operating circuit to relay M_c when the calling party releases first?

100. What opens the full operating and lock circuit to relay M_c when the calling party releases first?

101. What removes the hold circuit from the called line relay when the calling party releases first?

102. What opens the talking circuit to the called station when the calling station releases first?

103. What opens the operating circuit to relays F_c and D_c when the calling station releases first?

104. What opens the second lock from relay *C6* and the third lock from the calling line relay, *L2*, when the calling party releases first?

105. What opens the holding circuit of relay Z_c when the calling party releases first?

106. What opens the operating circuit to relay Z_c when the calling party releases first?

107. When the called party releases first, where is the loop opened to relay D_c?

108. Does the calling or called party have control for releasing the connector when the called party releases first?

109. What opens the operating circuit to relay B_c when the called party releases first?

110. What opens the first lock circuit to relay K_c on a release from a busy condition?

111. What completes the operating circuit to the connector-switch and minor-switch release magnets on a release from a busy condition?

112. What opens the operating circuit to relay Z_c on a release from a busy condition?

113. What completes the energizing circuit to the finder-release magnet (fig. 11–4) on a release from a busy condition?

114. How is executive right-of-way service usually obtained for a calling telephone?

115. Where is positive ground originated for an executive telephone?

116. What operates relay K_c when the dialed line is busy?

117. What completes the operating circuit to the (executive) relay, L_c, when the dialed line is busy?

118. What completes the executive talking circuit through to the called party when the dialed line is busy?

119. What opens the circuit to the busy tone lead so that normally the executive telephone does not hear busy tone?

120. What opens the operating circuit to relay L_c when the dialed line is busy?

121. What is meant by trunk hunting?

122. What four conditions must be met to make a telephone group trunk hunting?

123. What completes the operating circuit to the trunk hunting relay, J_c, on the third series of dialing?

124. What completes the second hold circuit to relay H_c and an operating circuit to the rotary magnets on the third series of dialing in a trunk hunting group?

125. What two actions occur when the connector rotary magnets operate on the third series of dialing in a trunk hunting group?

126. What prevents relay J_c from operating on the third series of dialing in a trunk hunting group when the wipers have stepped to the last trunk?

CHAPTER 12

DIAL TELEPHONE ALARM, RINGING, AND TESTING EQUIPMENT

ALARM SYSTEM

The dial telephone alarm system is an arrangement of signal equipment that gives an alarm if a nonstandard condition exists in the telephone system. The alarm consists of both an audible and a visual signal to indicate the nature and general location of the trouble.

The audible signal is a buzzer or bell that is common to all alarms; whereas, the visual signal is a lamp that is associated with a particular type of alarm. When the common alarm buzzer sounds, one or more alarm lamps will be lighted to indicate the nature of the trouble.

Nonstandard conditions cause either immediate or delayed alarms. For example, an immediate alarm is given when any fuse blows; whereas, a delayed alarm is given when a finder or connector fails to release after the normal releasing time of the switch has elapsed. Predetermined delay intervals are automatically provided by means of the timer relays for each type of alarm that requires a delay.

Lamp and Key Panel

The lamp and key panel (fig. 12–1) mounted on the front of the finder board contains all the alarm lamps for

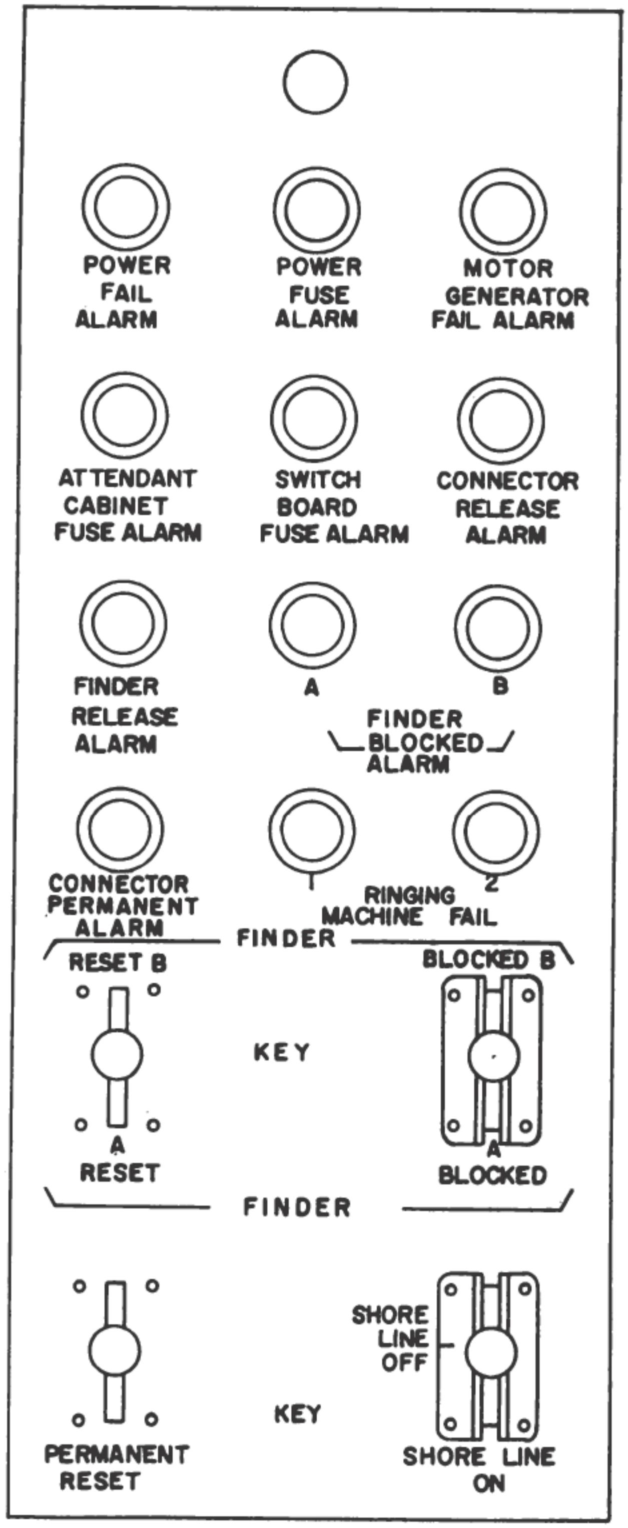


Figure 12—1.—Lamp and key panel.

the dial telephone system. The alarm lamps are the (1) power fail, (2) power fuse, (3) motor-generator fail, (4) attendant's cabinet fuse, (5) switchboard fuse, (6) connector release, (7) finder release, (8) finder blocked, A and B, (9) connector permanent, and (10) ringing machine fail, 1 and 2, alarms.

In addition to the alarm lamps, various switches (keys) are mounted on the lamp and fuse panel. These switches are the (1) finder reset, A and B, (2) finder blocked, A and B, (3) permanent reset, and (4) shore line control switches.

POWER FAIL ALARM.—The power fail alarm lamp (red) will light, and the common alarm buzzer will sound if the switchboard BATTERY VOLTS (maintained by the motor-generator and storage battery in parallel) falls below a predetermined value, or if the power supply fuse blows. This alarm is not provided with a delay interval. All alarms that light the POWER FAIL ALARM lamp should receive immediate attention because when this lamp is lighted the switchboard is completely out of service.

POWER FUSE ALARM.—The power fuse alarm lamp (red) will light, and the common alarm buzzer will sound if one or more of the fuses mounted on the power panel (except the voltmeter fuse) should blow. This alarm is not provided with a delay interval.

MOTOR-GENERATOR FAIL ALARM.—The motor-generator fail alarm lamp (red) will light because of (1) failure of the ship's 120-volt power supply, (2) operation of the controller overload contacts (or blown controller fuse), or (3) failure of the generator to cut in after the motor-generator has started. This alarm is so designed that its action is delayed from 15 to 45 seconds.

The POWER FAIL, POWER FUSE, and MOTOR-GENERATOR FAIL alarms are SUPERVISORY alarm lamps provided for the power equipment. The power panel and motor-generator are discussed with the power equipment in a separate chapter.

ATTENDANT'S CABINET FUSE ALARM.—The attendant's cabinet fuse alarm lamp (red) will light, and the common alarm buzzer will sound if a fuse associated with the attendant's cabinet should blow. This alarm is not provided with a delay interval.

SWITCHBOARD FUSE ALARM.—The switchboard fuse alarm lamp (red) on the lamp and key panel will light, and the common alarm buzzer will sound if any fuse mounted on the fuse panel should blow. This alarm is not provided with a delay interval.

CONNECTOR AND FINDER RELEASE ALARMS.—The connector release alarm lamp (green) or the finder release alarm lamp (green) will light, and the common alarm buzzer will sound if a connector or finder switch fails to release when the associated magnet circuit is closed. Each of these alarms is so designed that its action is delayed from 15 to 45 seconds.

The faulty finder or connector switch is located by plugging the hand test telephone (with button C depressed) in the test jack of each switch that is off-normal (if the switch is a finder, note the number and plug the hand test telephone in the correspondingly numbered connector). The hand test telephone is described later in this chapter with the testing equipment. If no conversation is heard, release button C and challenge. If no answer is received, release the switch that is off-normal by manually operating the release magnet. If this action does not extinguish the release alarm lamp, another switch is at fault.

If the cause of the release failure cannot be corrected immediately, make the defective switch busy by operating the BUSY KEY on the connector switch (fig. 11–7). This key makes busy both the connector and the correspondingly numbered finder. In other words, the busy key makes busy the finder-connector link. This action is necessary to prevent seizure of the link for another call until the defective switch is repaired or replaced by a new switch.

FINDER BLOCKED ALARM.—The finder blocked alarm lamp (red) will light, and the common alarm buzzer will sound if the finder allotted to a call fails to function, or fails to complete its function. Group A finders and group B finders are each equipped with an alarm lamp. This alarm is so designed that its action is delayed from 5 to 10 seconds.

If the blocked finder is in the A group of finders, the call at hand, and all subsequent calls, are transferred to the B group of finders. However, if a blocked-call condition or an all-finders-busy condition now appears in the B group, all calls will be transferred back to the A group, which will have stepped on to another finder. These transfers can continue back and forth indefinitely.

For example, if the A finder blocked alarm lamp is lighted, the defective finder can be determined by the following procedures:

1. Operate momentarily the FINDER RESET key to position A.

2. Operate the FINDER TEST key, mounted on the rear of the finder board, to position A.

3. Hold the FINDER TEST key operated to cause the A finders to step UP and IN, and release one after the other. This action will continue until the blocked finder is reached, at which time the B finders will start stepping.

   The blocked finder is the one located immediately after the last finder that functions properly in the A group. A finder that is properly UP and IN on a call should not be considered when determining the blocked finder.

   When the defective finder has been located, operate the busy key on the correspondingly numbered connector to "busy out" the finder-connector link until the defective finder can be repaired or replaced by a new switch.

4. Operate momentarily the FINDER RESET key to position A to again route calls to the A group of finders, thereby restoring normal operation.

A FINDER BLOCK key can be used to completely "busy out" either the A or B group of finders. This provision is useful when making repairs or replacements in the finder control and distributor equipment of the A or B group, and when performing routine maintenance.

CONNECTOR PERMANENT ALARM.—The connector permanent alarm lamp (white) will light, and the common alarm buzzer will sound if a PERMANENT occurs in the switchboard. A permanent is any condition that causes a finder-connector link to be held in an operated position when it is not being used for talking or dialing purposes. This alarm is so designed that its action is delayed from 4 to 8 seconds.

Some of the causes of permanents are:

1. A dislodged handset.
2. Failure of calling party to dial or to complete dialing.
3. Failure of either party to hang up at the termination of a call.
4. A short-circuited line, either inside or outside of the switchboard.
5. A grounded line on the negative side, either inside or outside of the switchboard.

When the common alarm buzzer sounds and the connector permanent lamp is lighted, the following procedures will be helpful in locating the permanent:

1. Operate momentarily the PERMANENT RESET key to stop the alarm buzzer and extinguish the CONNECTOR PERMANENT ALARM lamp. However, both alarms will operate again if the trouble is not cleared within approximately 4 to 8 seconds.
2. Plug the hand test telephone (with button C depressed) in the test jack of each successive connector switch. In the case of a connector that is at

normal, release button C and depress it again. This action should cause the connector to step up one step and then release. If the connector does not step, it is probably permanent. If a connector is off-normal and no dialing or talking is heard, release button C and challenge. If no answer is received, the connector is probably permanent.

3. When the permanent connector has been located, note the number of the switch and then examine the correspondingly numbered finder.
4. Determine the number of the faulty line by observing the position of the finder shaft and wiper assembly, and referring to the group A or group B finder banks designation card as the case may be. These designation cards are located inside the switchboard cabinet door.
5. Operate the line disconnect key of the faulty line. If the questionable finder releases, the trouble is not in the switchboard, but is at some point between the operated line disconnect key and the line station associated with that key. If the finder does not release, the trouble is in the switchboard.
6. Restore, when the trouble has been cleared, the line disconnect key to normal.

RINGING MACHINE FAIL ALARM.—The ringing machine fail alarm lamp (red) will light, and the common alarm buzzer will sound if the ringing machine fails to start or fails to supply ringing current to the ringing transformer. This alarm is not provided with a delay interval. Ringing machine 1 and ringing machine 2 are each provided with an alarm lamp. The ringing machine transfer switch (mounted on the ringing machine panel) is operated in position 1 or position 2, to select the ringing machine to be placed in service.

When the ringing machine fail alarm is operated, immediately operate the ringing machine transfer switch to the opposite position to start the idle ringing machine and

restore service to the switchboard. The faulty ringing machine can now be repaired.

COMMON ALARM BUZZER.—The common alarm buzzer used in the alarm system provides an audible signal in addition to the previously described visual alarm signals. It is designed for bulkhead mounting and is conveniently located on the side of the automatic switchboard. The buzzer (type Z2) operates on 50-volt a-c power supplied by a transformer (mounted on the power panel) that supplies power to the dial telephone system. When a nonstandard condition exists in the telephone system, the alarm buzzer operates immediately or after a predetermined delay, depending on the class of alarm.

RINGING EQUIPMENT

The ringing equipment consists of the ringing machine panel (fig. 12–2) on which are mounted the (1) ringing machines, (2) transfer key, and (3) test key. The ring-

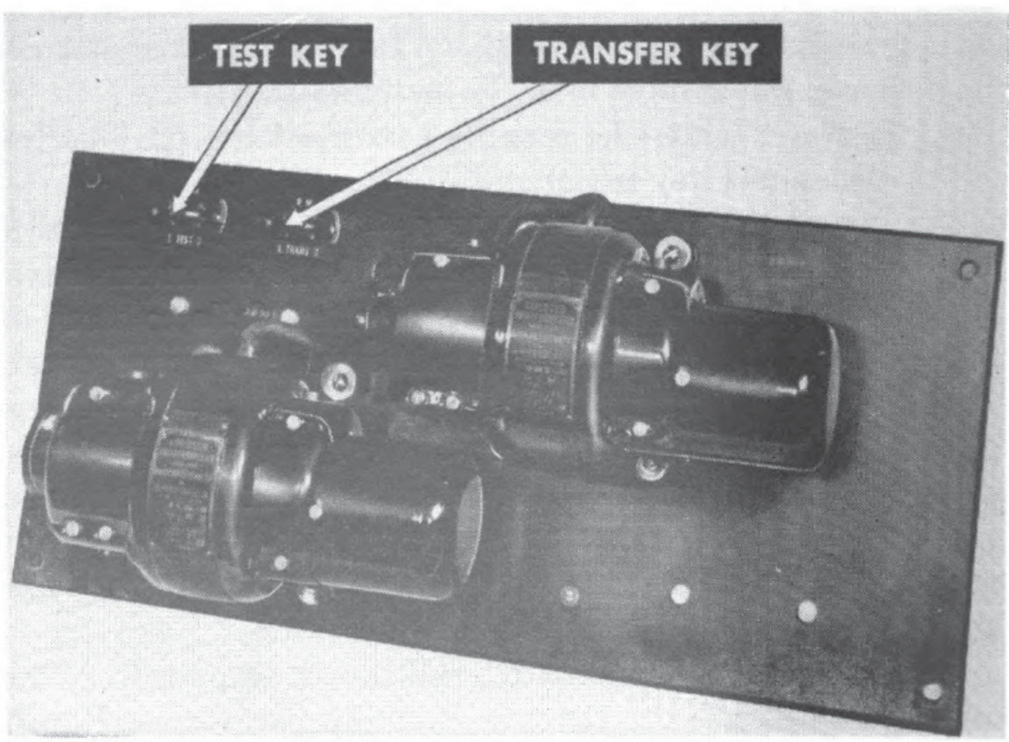


Figure 12—2.—Ring machine panel.

ing transformers, terminal block, and terminal strip are mounted on the rear of the panel (not shown).

Ringing Machines

Two separate ringing machines are provided with the ringing equipment, but only one machine is used at a time. The ringing machines supply dial, ring-back, and busy tones in addition to the regular ringing current.

The DIAL (steady buzzing) tone indicates to the calling station that dialing can commence. The ring-back, or ringing tone is suppressed ringing current that indicates that the connection has been completed and that ringing current is being delivered to the called station. The BUSY (rapid buzz-buzz) tone indicates that the called station is in use, or that an all-trunks-busy condition exists in the automatic switching equipment.

The ringing machine is an inverted rotary converter (fig. 12–3) that is supplied with d-c power from the power equipment. It consists of a 2-pole compound motor. The armature winding has two taps at diametrically opposite points. When the armature is rotated, a single-phase voltage is produced at the two slip rings that are connected to the two armature taps.

D-C MOTOR.—The d-c motor end (fig. 12–3, A) of the ringing machine has a pair of brushes that bear on a commutator. The ringing interrupter springs, which are actuated by a cam arrangement, are mounted on the commutator end of the ringing machine.

A-C GENERATOR.—The a-c generator end (fig. 12–3, B) of the ringing machine has a pair of generator brushes, a dial-tone brush, and a busy-tone brush. The generator brushes bear on two slip rings; whereas, the dial-tone and busy-tone brushes bear on the solid and intermittent sections respectively of a single slip ring.

The a-c generator brushes furnish 20-cycle ringing current at about 26 volts to the primary of a ringing transformer (mounted on the rear of the ringing machine

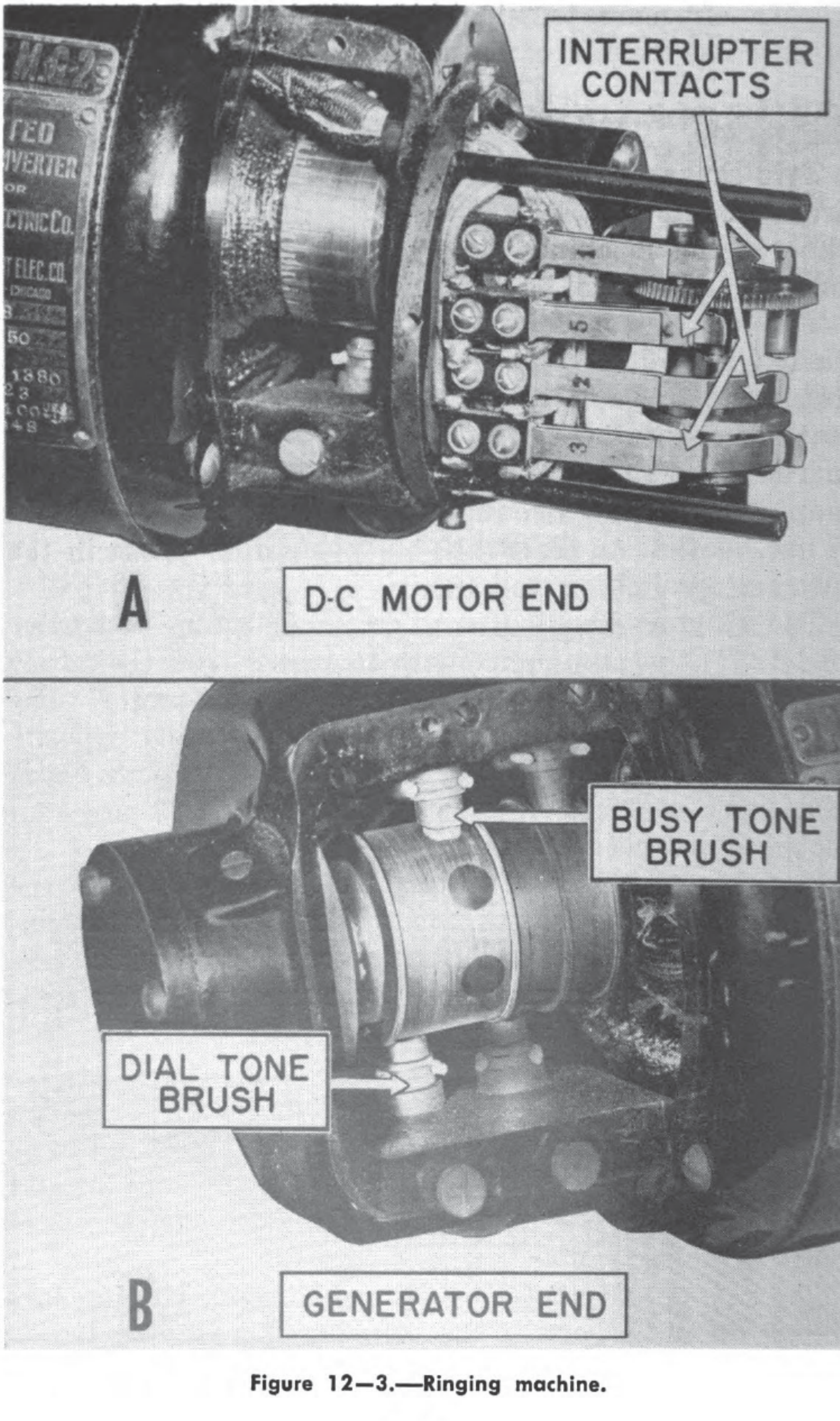


Figure 12—3.—Ringing machine.

panel). The secondary of this transformer feeds the 20-cycle ringing current at about 80 volts through the ringing interrupter springs to the connectors. The ringing interrupter springs provide a 1-second ringing period and a 3-second silent period in the ringing current.

The dial- and busy-tone brushes furnish 140 ground pulses per second to the primaries of two identical induction coils that produce the dial and busy tones respectively. Thus, the dial and busy tones are of the same basic frequency, but the busy tone passes through the busy interrupter springs, which provide interruptions at the rate of 117 per minute (approximately 2 per second) to distinguish it from the dial tone.

The timer interrupter springs provide a 4-second time pulse to the timer relays. These relays provide the various time intervals required for the delayed alarms previously discussed.

Ringing Machine Transfer Key

The ringing machine transfer key (fig. 12–2) has two positions for selecting the ringing machine to be placed in service. This switch transfers the MST lead from ringing machine 1 to ringing machine 2 and simultaneously transfers the RINGING MACHINE FAIL lamp 1 circuit to the RINGING MACHINE FAIL lamp 2 circuit. The ringing machine that is in service is started and stopped automatically as required by calls going through the switchboard.

Ringing Machine Test Key

The ringing machine test key (fig. 12–2) has two positions for starting either ringing machine. This arrangement permits operating the idle machine independently of the machine in service for periodic tests or repairs.

The ringing machines operate on d-c power supplied by the power equipment. The control equipment for automatically starting and stopping the machines is included with the ring and tone machine, timer, and alarm circuit.

Supervisory Control and Alarm Relays

The supervisory control and alarm relays, mounted on the front of the finder board, control the ring and tone machine, timer, and alarm circuits. These relays also control the associated timer circuit that provides the time intervals required for the delayed alarms.

RING AND TONE MACHINE, TIMER, AND ALARM CIRCUITS

The ring and tone machine, timer, and alarm circuits (fig. 12–4) are designed to provide various ringing codes and tones, alarm circuits, and an associated timer circuit for the dial telephone system.

Functions

The ring and tone machine, timer, and alarm circuits provide:

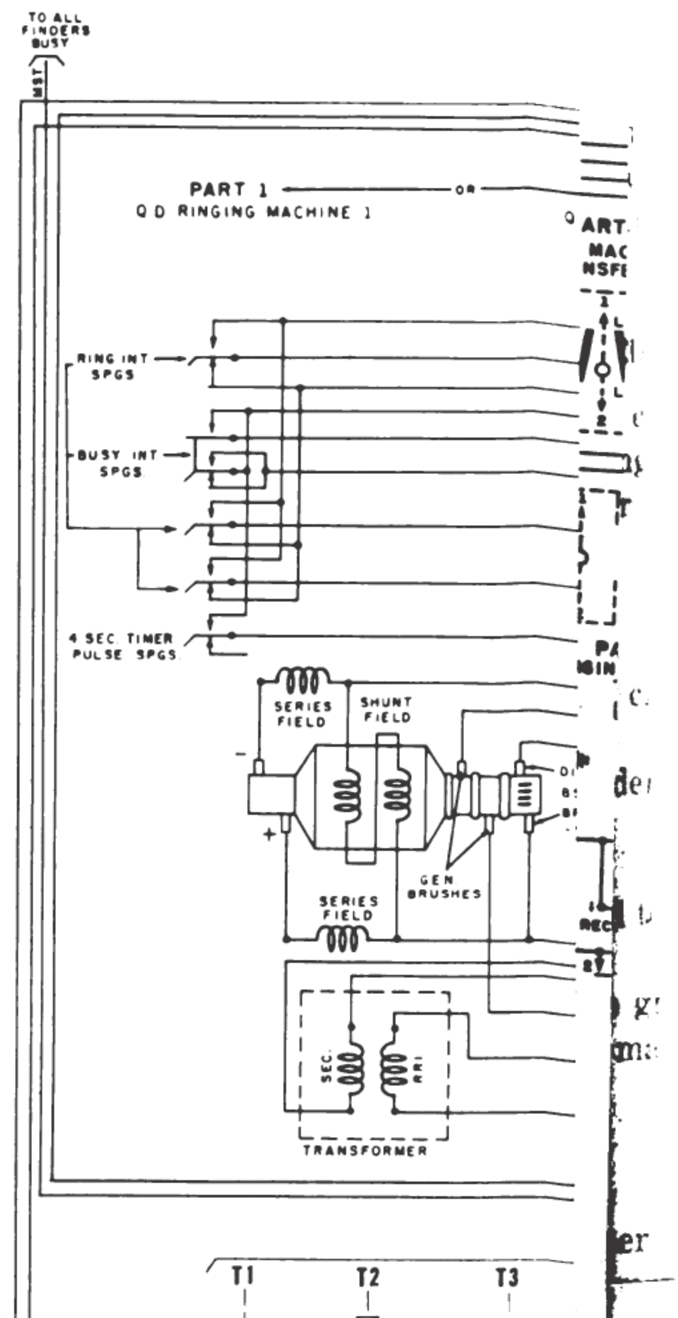
1. Delayed alarms from the connectors, the finders, the call allotter, and the ringing machine test.
2. Audible and visual alarm signals.
3. Transfer to the second ringing machine and testing of each machine.

The timer circuit is arranged for six separate ground pulses. The spring interrupter in the ringing machine circuit is the master control for the timer.

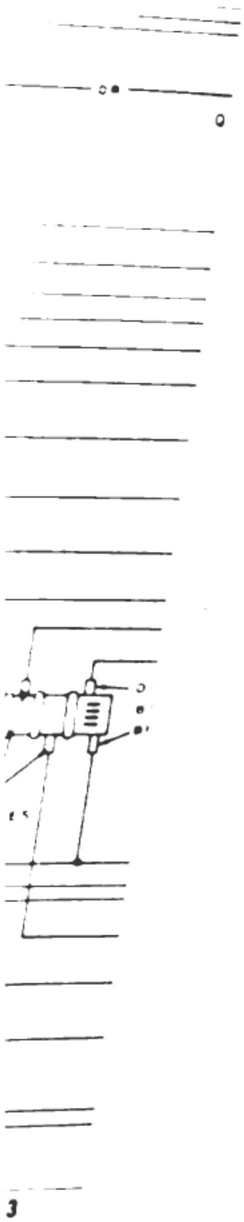
Timer Relays

It is important to remember the following timer relay rules to better understand the operation of the timer circuit:

1. TIMER RELAYS operate only on the upper windings.
2. TIMER RELAY *T*13 must be considered as an even relay.
3. ODD RELAYS get lock circuits on their upper windings.
4. EVEN RELAYS get hold circuits on their upper windings.



TO ALL FINDERS BUSY
MST
PART 1
OR
Q D RINGING MACHINE 1
RING INT SPGS
BUSY INT SPGS
4 SEC. TIMER PULSE SPGS
SERIES FIELD
SHUNT FIELD
GEN BRUSHES
SERIES FIELD
SEC.
PRI
TRANSFORMER
T1
T2
T3



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5. An ODD RELAY in operating or restoring does not cause relays to operate or restore.
6. ODD RELAY OPERATES:
   (a) Completes its own lock circuit.
   (b) Opens its own operating circuit.
   (c) Completes the operating circuit to the next even-numbered relay but that relay does not operate at this time.
7. ODD RELAY RESTORES:
   (a) Completes the holding circuit to the next even relay.
8. EVEN RELAY OPERATES:
   (a) Causes the next odd relay to either operate or restore.
9. EVEN RELAY RESTORES:
   (a) Causes the next even relay to either operate or restore.

The operation of the timer relays can be verified by referring to the timer relay chart.

TIMER RELAY CHART*

1st second	2, 3, 4 seconds	5th second	6, 7, 8 seconds	9th second	10, 11, 12 seconds	13th second	14, 15, 16 seconds
*T*13–O *T*1–O *T*1–L	*T*13–R *T*2–O *T*3–O *T*3–L	*T*13–O *T*1–R *T*2–H	*T*13–R *T*2–R *T*4–O *T*5–O *T*5–L	*T*13–O *T*1–O *T*1–L	*T*13–R *T*2–O *T*3–R *T*4–H	*T*13–O *T*1–R *T*2–H	*T*13–R *T*2–R *T*4–R *T*6–O *T*7–O *T*7–L

*NOTE:
O = Operates.
R = Restores.
H = Hold.
L = Lock.
Grounds FC1 and FC2 leads—4 seconds apart.
Grounds D1 and D2 leads—16 seconds apart.
Grounds P1 and P2 leads—4 minutes apart.

In the 100-line system, contacts 3–4 of finder control relay G4 place positive ground on the TST lead to complete the operating circuit to relay *T*14 in the timer cir-

cuit (part 9 of fig. 12–4). Relay *T*14 remains operated at all times during the operation of the timers.

RELAY *T*14 OPERATES:

1. Contacts 1–2 ground the MST lead.
2. Contacts 3–4 connect the TP lead to relay *T*13.
3. Contacts 5–6 prepare the circuits to windings 2 of relays *T*1 and *T*2.

The spring interrupter in the ringing machine circuit (part 1 or 3 of fig. 12–4) is the master control for the timer. The timer interrupter springs place ground (positive battery) on the TP lead every 4 seconds and completes the operating circuit to relay *T*13 by way of contacts 4–3 of relay *T*14 and contacts 6*B*–7*B* of relay *RC*3, which is operated during each 4 seconds pulse of the timer. The operation of relay *RC*3 is described later under Ringing Machine and Control Relays.

RELAY *T*13 OPERATES:

1. Contacts 1–2 complete the operating circuit of relay *T*1 and circuits to windings 1 and 2 of relay *T*2.
2. Contacts 3–4 prepare ground to the FC2 and D2 leads.

Relay *T*2 does not operate at this time because its coils are in opposition.

RELAY *T*1 OPERATES:

1. Contacts 2–3 connect ground to the FC2 and the D2 leads.
2. Contacts 4–6 complete its own lock circuit by transferring the ground of winding 2 of relay *T*1 to ground at relay *T*14.
3. Contacts 5–6 open the operating circuit to relay *T*1.

RELAY *T*13 OPERATES (when the timer pulse springs remove ground from the TP lead):

1. Contacts 1–2 open the circuit to winding 1 of relay *T*2.
2. Contacts 3–4 remove ground from the FC2 and D2 leads.

Relay *T*2 operates:

1. Contacts 1–2 open a part of the circuit of the FC2 lead.
2. Contacts 4–5 prepare a circuit to winding 1 of relay *T*1.
3. Contacts 6–7 prepare a circuit to the P1 and FC1 leads.
4. Contacts 8–9 complete the operating circuit to relay *T*3 and a circuit to windings 1 and 2 of relay *T*4.

Relay *T*4 does not operate at this time because its coils are in opposition.

Relay *T*3 operates:

1. Contacts 1–2 open part of the circuit to the P1 lead.
2. Contacts 5–7 complete its own lock circuit and the operating circuit for relay *T*4.

Relay *T*4 does not operate because its windings are in opposition.

After 4 seconds ground is again connected to the TP lead.

Relay *T*13 operates:

1. Contacts 1–2 complete the circuit to winding 1 of relay *T*1 and relay *T*1 restores.

Relay *T*1 restores (coils differentially connected):

1. Contacts 1–2 ground the FC1 lead and prepare ground to the P1 lead.
2. Contacts 4–6 open the operating circuit to relay *T*2.
3. Contacts 5–6 complete the hold circuit to relay *T*2.

Relay *T*13 restores (when ground is again removed from the TP lead by the timer pulse springs opening):

1. Contacts 1–2 open the hold circuit to relay *T*2.
2. Contacts 3–4 remove ground from the FC1 lead.

Relay *T*2 restores:

1. Contacts 6–7 open part of the incomplete circuit to the P1 and the FC1 leads.

2. Contacts 3–4 prepare ground to winding 1 of relay *T*2.
3. Contacts 4–5 open part of the circuit to winding 1 of relay *T*1.
4. Contacts 8–9 open the holding circuit to relay *T*4 by removing ground from its winding 1. (winding 2 is energized through contacts 5–7 of relay *T*3).

RELAY *T*4 OPERATES:

1. Contacts 1–2 open a part of the circuit of winding 1 of relay *T*4.
2. Contacts 2–3 prepare a circuit to winding 1 of relay *T*3.
3. Contacts 4–5 complete the operating circuit to relay *T*5 and circuits to windings 1 and 2 of relay *T*6.
4. Contacts 6–7 prepare a circuit to the P1 lead.
5. Contacts 8–9 prepare a circuit to the P2 lead.

RELAY *T*5 OPERATES:

1. Contacts 1–2 open the circuit to the D2 lead.
2. Contacts 4–6 complete the lock circuit to relay *T*5 and complete the operating circuit to relay *T*6.

Relay *T*6 does not operate because its windings are in opposition.

3. Contacts 5–6 open the operating circuit to relay *T*5.

After 4 seconds, ground is again connected to the TP lead.

RELAY *T*13 OPERATES (relays *T*3, *T*4, *T*5, and *T*14 energized):

1. Contacts 1–2 complete the operating circuit to relay *T*1 and completes circuits to windings 1 and 2 of relay T2. Relay *T*2 does not operate because its windings are in opposition.

RELAY *T*1 OPERATES:

1. Contacts 2–3 connect ground to the FC2 and the D2 leads.

2. Contacts 4–6 complete its (relay T1) own lock circuit by transferring the ground of winding 2 of relay $T1$ to ground at relay $T14$ and completes the operating circuit to relay $T2$. Relay T2 does not operate because its windings are in opposition.
3. Contacts 5–6 open the operating circuit to relay $T1$.

RELAY $T13$ RESTORES (when ground is removed from the TP lead by the timer pulse springs opening):

1. Contacts 1–2 open the circuit to winding 1 of relay $T2$.
2. Contacts 3–4 remove ground from the FC2 and D2 leads.

RELAY $T2$ OPERATES (winding 2 remains energized through contacts 4–6 of relay $T1$ and the $T14$ ground):

1. Contacts 4–5 prepare a circuit to winding 1 of relay $T1$.
2. Contacts 8–9 complete a circuit to winding 1 of relay $T3$ (winding 2 of relay $T3$ remains energized through its contacts 5–7 and the $T14$ ground).

Relay $T3$ restores because its coils are differentially connected.

RELAY $T3$ RESTORES (relays $T1$, $T2$, $T4$, $T5$, and $T14$ operated):

1. Contacts 5–7 open the operating circuit to relay $T4$.
2. Contacts 6–7 complete the hold circuit to relay $T4$ by way of contacts 8–9 of relay $T2$ and the $T14$ ground.

The next time relay $T13$ operates by the timer pulse springs closing (relays $T1$, $T2$, $T4$, $T5$, and $T14$ operated), contacts 1–2 complete the circuit to winding 1 of relay $T1$ and relay $T1$ restores.

RELAY $T1$ RESTORES (its windings in opposition):

1. Contacts 1–2 place ground on the FC1 lead.
2. Contacts 5–6 complete the hold circuit to relay $T2$.

3. Contacts 4–6 open the operating circuit to relay *T*2.

THE TIMER PULSE SPRINGS OPEN AND RELAY *T*13 RESTORES:

1. Contacts 1–2 open the hold circuit to relay *T*2 and relay *T*2 restores.
2. Contacts 3–4 remove ground from the FC1 lead.

RELAY *T*2 RESTORES:

1. Contacts 8–9 open the hold circuit to relay *T*4.

RELAY *T*4 RESTORES:

1. Contacts 1–2 prepare a circuit to winding 1 of relay *T*4.
2. Contacts 2–3 open a part of the circuit to winding 1 of relay *T*3.
3. Contacts 4–5 open the circuit of winding 1 of relay *T*6 and relay *T*6 operates.

RELAY *T*6 OPERATES:

1. Contacts 12–13 complete the operating circuit to relay *T*7 and relay *T*7 energizes.

RELAY *T*7 OPERATES:

1. Contacts 1–3 complete its own lock circuit.

This relay action continues until all of the relays up to relay *T*12 inclusive have operated.

This relay action continues until all of the relays, *T*1 to *T*12 inclusive, have operated. Relay *T*1 operates when relay *T*13 operates the first time. Relay *T*1 restores when relay *T*13 operates the second time. This cycle of operation is then repeated.

Relay *T*2 operates the first time relay *T*13 restores, and relay *T*2 restores the second time relay *T*13 restores.

Relay *T*3 operates the first time relay *T*2 operates, and relay *T*3 restores the second time relay *T*2 operates.

Relay *T*4 operates the first time relay *T*2 restores, and relay *T*4 restores the second time relay *T*2 restores. The cycle of operation is repeated once it is completed, and progresses from relay group to relay group. This cycle of operation is indicated by the timer relay chart. A

group consists of two relays, as $T1$–$T2$, $T3$–$T4$, and so on. Relay $T4$ then controls relays $T5$ and $T6$; relay $T6$ controls relays $T7$ and $T8$ and so on. Figure 12–5 represents the sequence of operation of the timer relays and their associated pulses.

Ringing Machine and Control Relays

Ground is placed on the MST lead by contacts 1–2 of relay $T14$ through the ringing machine transfer switch (part 5 of fig. 12–4) to complete the operating circuit to winding 1 of relay $RC2$ (part 4).

RELAY $RC2$ OPERATES:

1. X contacts (1–2) complete a circuit to start the ringing machine through resistors F and G.
2. Contacts 4–5 complete a circuit to bypass resistor G, which increases the speed of the ringing machine and shunts relay $RC1$ with resistor F.

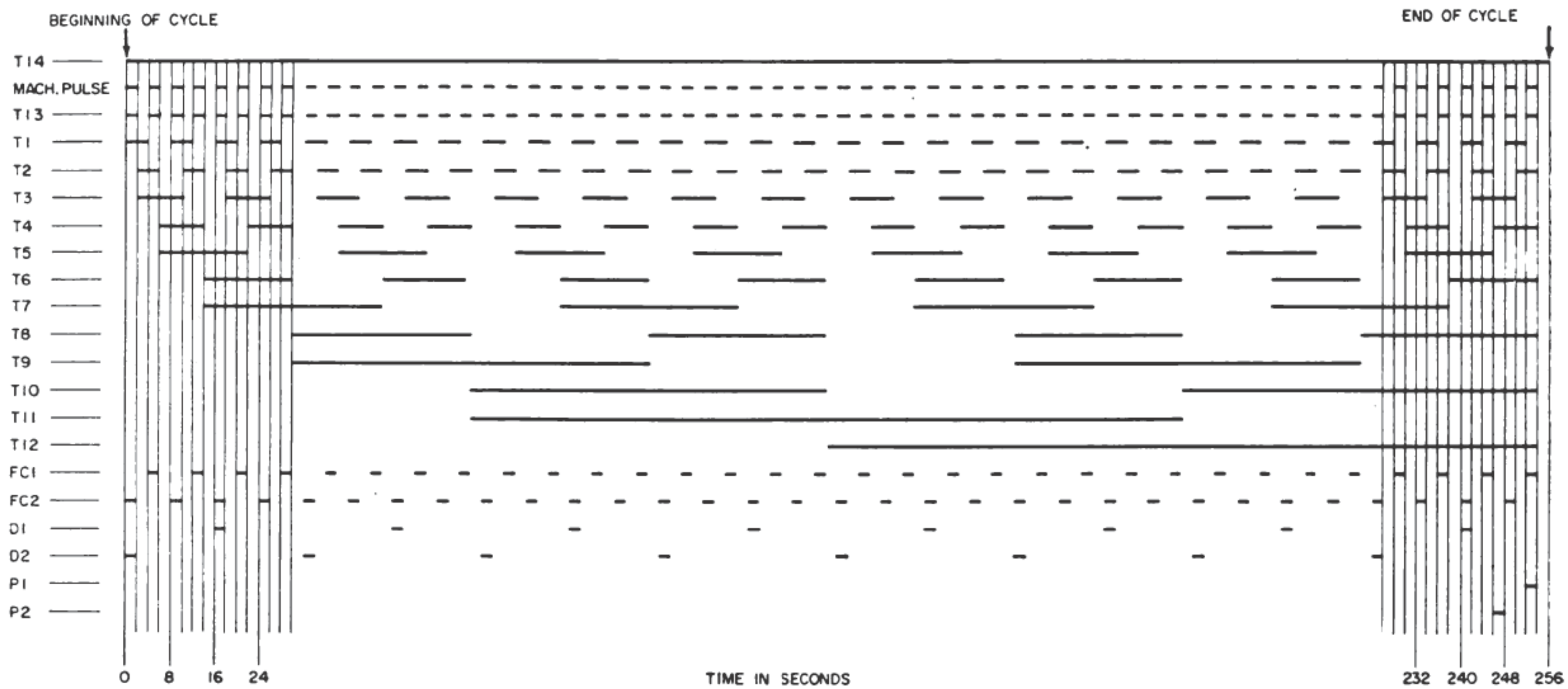
This action brings the ringing machine up to speed.

3. Contacts 6–7 prepare a circuit to relay $RC3$.
4. Contacts 8–9 complete the second lock circuit to relay $RC2$.
5. Contacts 10–11 complete its first lock circuit.

Relay $RC1$ is operated at all times through the ST lead.

RELAY $RC1$ RESTORES (shunted):

1. Contacts 1–2 open the first lock circuit to relay $RC2$.
2. Contacts 3–4 complete the operating circuit to relay $RC3$.
3. Contacts 4–5 open the operating circuit to relay $RC2$. Relay $RC2$ does not restore because of its lock circuit through its contacts 8–9.
4. Contacts 6–7 connect direct ground on the ST lead to place the ringing machine across the line.
5. Contacts 8–9 complete the primary transformer circuit of the insulating transformer (part 1 of fig. 12–4).
6. Contacts 10–11 prepare the busy- and dial-tone circuits.



NOTE:

1. LINES INDICATE THE TIME THAT EACH RELAY IS OPERATED OR THAT GROUND IS ON THE PARTICULAR LEAD.
2. THE MACH. PULSE IS ACTUALLY A 4 SECOND PULSE CONSISTING OF GROUND FOR 1 SECOND AND NO POTENTIAL FOR 3 SECONDS.
3. ONE CYCLE IS COMPLETED IN 256 SECONDS.

Figure 12—5.—Sequence of operation of timer relays and associated pulses.

RELAY $RC3$ OPERATES:

1. Contacts $1T$–$2T$ open the operating circuit to relay $RM1$.
2. Contacts $3T$–$4T$ complete the operating circuit to the DIR GEN lead and the operating circuit to relay $RM2$ (part 6 of fig. 12–4).
3. Contacts $5T$–$6T$ connect the IG1A lead to the interrupter springs from the INT GEN1 lead.
4. Contacts $7T$–$8T$ connect the IG2A lead to the interrupter springs from the INT GEN2 lead.
5. Contacts 2B–3B complete the BUSY TONE circuit through the tone distribution circuit to the connector switch jack.
6. Contacts $4B$–$5B$ complete the DIAL TONE circuit through the tone distribution circuit to the connector switch jacks.
7. Contacts $6B$–$7B$ prepare the operating circuit to relay $T13$.
8. Contacts $8B$–$9B$ connect the IG3A lead to the interrupter springs from the INT GEN3 lead (prepare the ringing circuit to the connector switch jacks).

When the circuit is completed to the DIR GEN lead, it completes the circuit to relay $RM2$. Ground return on the secondary of the insulating transformer is through winding 1 of relay F_c (fig. 11–7), the minor switch, and contacts $6B$–$7B$ of relay M_c. The rectifier across relay $RM2$ acts as a short circuit during one-half of the ringing current cycle, and as a high resistance during the remaining half of the cycle. Hence, relay $RM2$ receives a pulsating current. This current is of more than one-half cycle duration because the induced emf in the relay coil is in the forward direction of the rectifier on alternate half cycles of the ringing generator. Therefore, relay $RM2$ has less tendency to chatter. Resistor B in the rectifier circuit of relay $RM2$ limits the current to protect the rectifier.

RELAY *RM*2 OPERATES:

1. Contacts 1–2 complete a holding circuit to relay *RM*3.

RELAY *RM*1 RESTORES:

1. Contacts 1–2 open the operating circuit of relay *RM*3.

RELAY *RM*3 OPERATES:

1. Contacts 1–2 complete the operating circuit to relay *RM*4.

RELAY *RM*4 OPERATES:

1. Contacts 1–2 and 3–4 open the ringing machine fail lamp circuits.
2. Contacts 5–6 open the A and AG leads to the alarm buzzer.

With ground on the ST lead to terminal 2 of the RM panel, the ringing machine is now prepared to deliver (1) ringing current to its associated IG1A, IG2A, and IG3A leads; (2) dial tone to the DTC lead; and (3) busy tone to the BTC lead. The ringing machine breaks the ringing current into codes by means of its cam-operated interrupter springs.

The dial- and busy-tone brushes deliver 140 IPS (interruptions per second) to windings 1–2 of the dial- and busy-tone induction coils. This current is induced in windings 3–4 of these induction coils. Dial tone is furnished continuously at 140 IPS to the DTC lead. Busy tone is furnished at the rate of 117 IPM (interruptions per minute). Each busy-tone impulse is composed of 140 IPS dial-tone current. The busy interrupter springs interrupt the dial tone at 117 IPM.

Ringing Machine Test Relays

Under normal operation, relay *RM*2 operates and relay RM1 (part 6 of fig. 12–4) restores as previously explained. However, if the ringing machine in service should fail, the circuit will be deenergized to relay *RM*2.

RELAY *RM*2 RESTORES:

1. Contacts 1–2 open the hold circuit to relay *RM*3.

RELAY *RM*3 RESTORES:

1. Contacts 1–2 open the operating circuit to relay *RM*4.

RELAY *RM*4 RESTORES:

1. Contacts 1–2 or 3–4 complete a circuit to the ringing machine fail lamp, 1 or 2, associated with the ringing machine that failed.
2. Contacts 5–6 complete a circuit to an audible alarm.

When the ringing machine is restored to normal operation, relay *RM*2, *RM*3, and *RM*4 re-operate.

Ringing Machine Transfer Switch

The ringing machine transfer switch transfers the MST lead from one ringing machine to the other and simultaneously transfers the ringing machine fail lamp circuit to the corresponding fail lamp.

Ringing Machine Test Switch

The ringing machine test switch permits the ringing machine to be started for routine testing. However, when the test switch is operated only, relay *RC*1 releases. The other relays do not operate because it is not the purpose of the test to connect ringing current to the various associated circuits.

Motor-Generator Failure Relays

When the motor-generator in the power equipment fails, ground (+ battery) is placed on the CFR lead by contacts 1–2 of relays *PC*1 and *PC*4 on the power panel. The action that places ground on the CFR lead is described with the power equipment in a separate chapter. This ground completes the operating circuit to motor-generator failure relay *CS*1 (part 8 of fig. 12–4).

RELAY *CS*1 OPERATES:

1. Contacts 1–2 complete a circuit to the TST lead to start the TIMER (relay T14).
2. Contacts 3–4 prepare the operating circuit to relay *CS*3.

3. Contacts 5–6 prepare the lock circuits for relays *CS*2 and *CS*3.

Within a few seconds the TIMER will connect ground to the D1 lead, thereby completing the circuit to winding 1 of relay *CS*3. The circuit is from the D1 lead, through contacts 10–11 of relay *T*6 (operated), through contacts 2–3 of relay *T*5 (operated), through contacts 1–2 of relay *T*2 (restored), through contacts 2–3 of relay *T*1 (operated) and contacts 3–4 of relay *T*13 (operated) to ground.

RELAY *CS*3 OPERATES:

1. Contacts 1–2 prepare the operating circuit of relay *CS*2.
2. Contacts 3–4 complete its (relay *CS*3) lock circuit.

Within a few seconds the TIMER removes ground from the D1 lead and places ground on the D2 lead (relay *T*6 restores), thereby completing the circuit to winding 1 of relay *CS*2.

RELAY *CS*2 OPERATES:

1. Contacts 1–2 open the operating circuit of relay *CS*3.
2. Contacts 3–4 open the circuit to the TST lead to the TIMER and relay *T*14 restores.
3. Contacts 4–5 complete the circuit to the MOTOR-GENERATOR FAIL lamp.
4. Contacts 6–7 complete the circuit to an audible alarm signal (buzzer or bell) by shorting the A and AG leads.
5. Contacts 8–10 complete its (relay *CS*2) lock circuit.
6. Contacts 9–10 open the lock circuit of relay *CS*3.

The TIMER removes ground from the D2 lead after a predetermined interval and stops operating.

RELAY *CS*3 RESTORES:

1. Contacts 1–2 open the operating circuit of relay *CS*2.
2. Contacts 3–4 open its (relay *CS*3) lock circuit.

When the motor-generator again operates satisfactorily, the ground will be removed from the CFR lead, thereby opening the circuit to relay *CS*1.

RELAY *CS*1 RESTORES:

1. Contacts 1–2 open an incomplete circuit to the TST lead.
2. Contacts 3–4 open the incomplete operating circuit of relay *CS*3.
3. Contacts 5–6 open the lock circuit of relay *CS*2.

RELAY *CS*2 RESTORES:

1. Contacts 1–2 prepare the operating circuit for relay *CS*3.
2. Contacts 3–4 prepare the circuit to relay *T*14 for future motor-generator fail alarm.
3. Contacts 4–5 open the circuit to the MOTOR-GENERATOR FAIL lamp.
4. Contacts 6–7 open the short on the A and AG leads and the alarm buzzer.
5. Contacts 8–10 open its (relay *CS*2) incomplete lock circuit.
6. Contacts 9–10 prepare the lock circuit of relay *CS*3.

The circuit is now at normal.

Fuse Alarm Relay

When any fuse blows, the circuit is completed from negative battery at the blown fuse through the fuse lamp and relay *FA* (part 7 of fig. 12–4) to ground.

FUSE ALARM RELAY OPERATES:

1. Contacts 1–2 short the A and AG leads to complete the circuit to the alarm buzzer.

The fuse alarm relay remains operated until the blown fuse is removed and replaced with a new fuse.

CONNECTOR-SYSTEM TONE DISTRIBUTION AND ALARM CIRCUITS

The connector-system tone distribution and alarm circuits (fig. 12–6) are designed to provide tone distribution and alarm relays for the automatic switchboard.

Functions

The connector-system tone distribution and alarm circuits provide:

1. Distribution of busy and dial tones to connectors.
2. An alarm if a finder or connector fails to release.
3. An alarm if a PERMANENT condition occurs in a connector. The alarm can be released by the reset key.
4. Motor start when a connector is seized.

Tone Distribution Circuit

BUSY TONE.—The interrupted (busy) tone current and ground are supplied from the ringing machine control relays (parts 2 and 4 of fig. 12–4) over the BTC and + BAT leads respectively to the tone distribution circuit (part 1 of fig. 12–6).

The busy tone is connected through capacitors C and D in the tone distribution circuit to the finders and connectors that provide the REGULAR busy tone and ALL FINDERS busy tone.

The busy tone is connected through capacitor C over the BTC lead to the connectors (fig. 11–7) for the REGULAR busy tone. The busy tone is connected through capacitor D over the AFBT lead to contacts 4–5 of relay FB9 (part 9 of fig. 11–4) for ALL FINDERS busy tone.

When all finders are busy, the *F*4 relays in both the A and B finder control groups are released (part 4 and 4A of fig. 11–4). Contacts 1–2 of finder control relay *F*4 place ground from SJ31 on the AFB lead to complete the operating circuit to relay *FB*9 (part 9 of fig. 11–4).

RELAY *FB*9 OPERATES:

1. Contacts 1–2 remove ground from the APB lead.
2. Contacts 2–3 place ground on the MST lead.
3. Contacts 4–5 place busy tone from the AFBT lead to the APB lead through windings 1–2 and 1–4 of induction coils *FB*1 and *FB*2 respectively.

Ground on the MST lead starts the ringing (ring and tone) machine, as previously described under ringing

TO FINDERS

TO ALL FINDERS
BUSY RELAY

TO CONNECTOR

machine and control relays. The *FB*1 and *FB*2 induction coils reduce cross induction of the busy tone.

When a finder is released, the circuit to relay *FB*9 over the AFB lead is opened by relay *F*4 in the finder-control circuit.

RELAY *FB*9 RESTORES:

1. Contacts 1–2 place positive ground on the APB lead to relay *L*2.
2. Contacts 2–3 remove ground from the MST lead.
3. Contacts 4–5 remove busy tone from the AFB lead.

DIAL TONE.—The continuous (dial) tone current and ground are supplied from the ringing machine control relays (parts 2 and 4 of fig. 12–4) over the DTC and +BAT leads respectively to the tone distribution circuit (part 1 of fig. 12–6).

The dial-tone current flows through capacitor A and winding 2–3 of dial-tone induction coil 1, to ground. The dial-tone current also flows through capacitor B and winding 2–3 of dial-tone induction coil 2, to ground. Dial-tone current is induced in windings 1–4 of dial tone induction coils 1–2, and is supplied over the DT1 and DT2 leads respectively to the connectors (fig. 11–7).

Finder and Connector Release Alarm Circuits

FINDER RELEASE ALARM.—When a line finder release magnet operates, release signal springs 1–2 place ground on the FR SIG lead to complete the operating circuit to relay *R*2 in the finder and connector release circuit (part 3 of fig. 12–6).

RELAY *R*2 OPERATES:

1. Contacts 1–2 open the CR SIG lead to the connector (fig. 11–6).
2. Contacts 3–4 connect the D1 lead to winding 1 of relay *R*4 and prepares the operating circuit of relay *R*4.
3. Contacts 5–6 prepare a lock circuit to relay *R*4.

4. Contacts 7–8 place ground on the TST lead to operate relay $T14$ and start the timer.
5. Contacts 9–10 prepare a circuit to the FINDER RELEASE lamp.

RELAY $T14$ OPERATES:

1. Contacts 1–2 complete the operating circuit to relay $RC2$ which starts the ringing machine.
2. Contacts 3–4 prepare the operating circuit to relay $T13$, which will start the timers.

After a short time delay, contacts 2–3 of relay $T1$ (fig. 12–4) will operate to complete the operating circuit to relay $R4$ by placing a ground on the D1 lead. This ground will remain on the D1 lead for one second.

RELAY $R4$ OPERATES:

1. Contacts 1–2 prepare the operating circuit to relay $R3$ over the D2 lead.
2. Contacts 3–4 complete its (relay R4) lock circuit through winding 2.

After a delay of 16 seconds, the relay $T1$ places ground on the D2 lead, completing the operating circuit to relay $R3$. This ground remains on the D2 lead for one second.

RELAY $R3$ OPERATES:

1. Contacts 3–4 open the operating circuit to relay $T14$.
2. Contacts 4–5 complete the circuit to the FINDER RELEASE lamp.
3. Contacts 6–7 short the A and AG lead to start the alarm buzzer (fig. 12–4).
4. Contacts 9–10 open the lock circuit to relay $R4$.
5. Contacts 8–10 complete its (relay $R3$) lock circuit under control of relay $R2$.

RELAY $R4$ OPERATES:

1. Contacts 1–2 open the operating circuit to relay $R3$.
2. Contacts 3–4 open part of the its lock circuit.

Ordinarily the shaft of the line finder returns to normal, and release signal springs 1–2 (part 6 of fig. 11–4) will

remove ground from the FR SIG lead to relay $R2$ in the release circuit before relay $R3$ operates, thereby eliminating an alarm each time a finder restores. Relays $R2$ and $R4$ (if operated) restore, restoring the finder and connector release circuit to normal. If the shaft of the line finder does not return to normal, ground on the FR SIG lead will operate relays $R2$ and $R3$, and the FINDER RELEASE ALARM lamp will light. This alarm lamp will remain lighted until the finder switch shaft is returned to normal and relays $R2$ and $R3$ restore, restoring the release circuit to normal.

CONNECTOR RELEASE ALARM.—If a connector fails to release when its release magnet is operated, relay Z_c is held operated through the SVON springs 3–4 (fig. 11–4). Normally, contacts 1–2 of relay B_c (restored) place ground on the CR SIG lead through contacts 6–7 of relay Z_c. Ground on the CR SIG lead completes the operating circuit to relay $R1$ in the finder and connector release circuit (part 3 of fig. 12–6). The action from this point on is similar to that of the previously described finder release alarm, except that relay $R1$ operates instead of relay $R2$.

Connector Permanent Alarm Circuit

The CONNECTOR PERMANENT ALARM lamp will light when a connector permanent occurs. When a connector is preseized, contacts 9–10 of relay B_c place a ground on the C PERM lead to complete the operating circuit to relay $P1$ in the connector permanent circuit (part 2 of fig. 12–6).

RELAY $P1$ OPERATES:

1. Contacts 1–2 prepare a circuit from the $P1$ lead to relay $P3$.
2. Contacts 3–4 prepare a locking ground for relays $P2$ and $P3$.
3. Contacts 5–6 place ground on the TST lead to operate relay $T14$ in the TIMER.

4. Contacts 7–8 place ground on the MST lead to keep the ringing machine running after relay *P*2 operates.

RELAY *T*14 OPERATES:

1. Contacts 1–2 complete the operating circuit to relay *RC*2, which starts the ringing machine.
2. Contacts 3–4 prepare the operating circuit to relay *T*13, which will start the TIMERS.

After a short delay, relay *T*1 will restore to complete the operating circuit to relay P3 by placing ground on the P1 lead. This ground will remain on the P1 lead for one second.

RELAY *P*3 OPERATES:

1. Contacts 1–2 complete its (relay *P*3) lock circuit through winding 2.
2. Contacts 3–4 prepare the operating circuit from the P2 lead to winding 1 of relay *P*2.

After a delay of 4 minutes contacts 2–3 of relay *T*1 (operated) place ground on the P2 lead to complete the operating circuit to winding 1 of relay *P*2.

RELAY *P*2 OPERATES:

1. Contacts 1–2 remove winding 1 of relay *P*3 from the P1 lead.
2. Contacts 3–4 open the operating circuit to relay *T*14.
3. Contacts 4–5 complete the circuit over the CPL lead to the CONNECTOR PERMANENT lamp.
4. Contacts 6–7 short the A and AG leads to start the alarm buzzer.
5. Contacts 9–10 open the lock circuit to relay *P*3.
6. Contacts 8–10 complete its lock circuit through winding 2 to ground at the PERMANENT RESET key.

RELAY *P*3 RESTORES:

1. Contacts 1–2 open part of its (relay *P*3) lock circuit.
2. Contacts 3–4 open the operating circuit to relay *P*2.

The CONNECTOR PERMANENT alarm will continue until relay P1 restores. Normally, ground will be removed from the C PERM lead before relay *P*2 has time to operate, thereby eliminating an alarm each time a connector is used. The PERMANENT RESET key (part 6 of fig. 12–6) is operated momentarily to restore relay *P*2 and silence the alarm while locating the trouble.

RELAY *P*2 RESTORES:

1. Contacts 3–4 place ground on the TST lead to start the TIMER.
2. Contacts 4–5 open the circuit to the CONNECTOR PERMANENT lamp.
3. Contacts 6–7 open the A and AG leads to stop the buzzer.
4. Contacts 8–10 open the lock circuit to relay *P*2.

After a time interval (from 4 to 8 minutes) during which the TIMER cycle occurs, ground is again placed on the P2 lead, causing relay P2 to operate. When relay *P*2 operates, the alarms are again actuated as previously explained. If the trouble is cleared during this interval, relay *P*1 will restore, restoring this circuit to normal.

FUSE LAMP.—When a fuse blows, a circuit is completed through the fuse lamp (part 4 of fig. 12–6). The lamp will remain lighted until the blown fuse is removed. The circuit is from negative battery, to the fuse bar, the fuse lamp, the fuse alarm relay, and ground.

TESTING EQUIPMENT

Testing equipment is provided for use in detecting and locating nonstandard conditions in the dial telephone system. This equipment comprises (1) a line disconnect key panel, (2) a hand test telephone, (3) a test set, and (4) a portable resistance test box for conducting spring-margining tests on relay springs. The use of the resistance test box and the procedure for performing these tests are contained in the manufacturers' instruction book.

Line Disconnect Key Panel

The line disconnect key panel (fig. 12–7) mounted on the front of the finder board is equipped with 100 keys (one for each line connected to the switchboard). Thus, any line can be disconnected from the switchboard for testing purposes, isolating a faulty line, or cutting out nonessential lines when required. Each line disconnect key has the same number as its associated line. When the key is in the normal position, the telephone line is connected to the associated line relay in the automatic switchboard. When the line disconnect key is operated (pulled out) the connection is opened between the telephone line and the associated line relay.

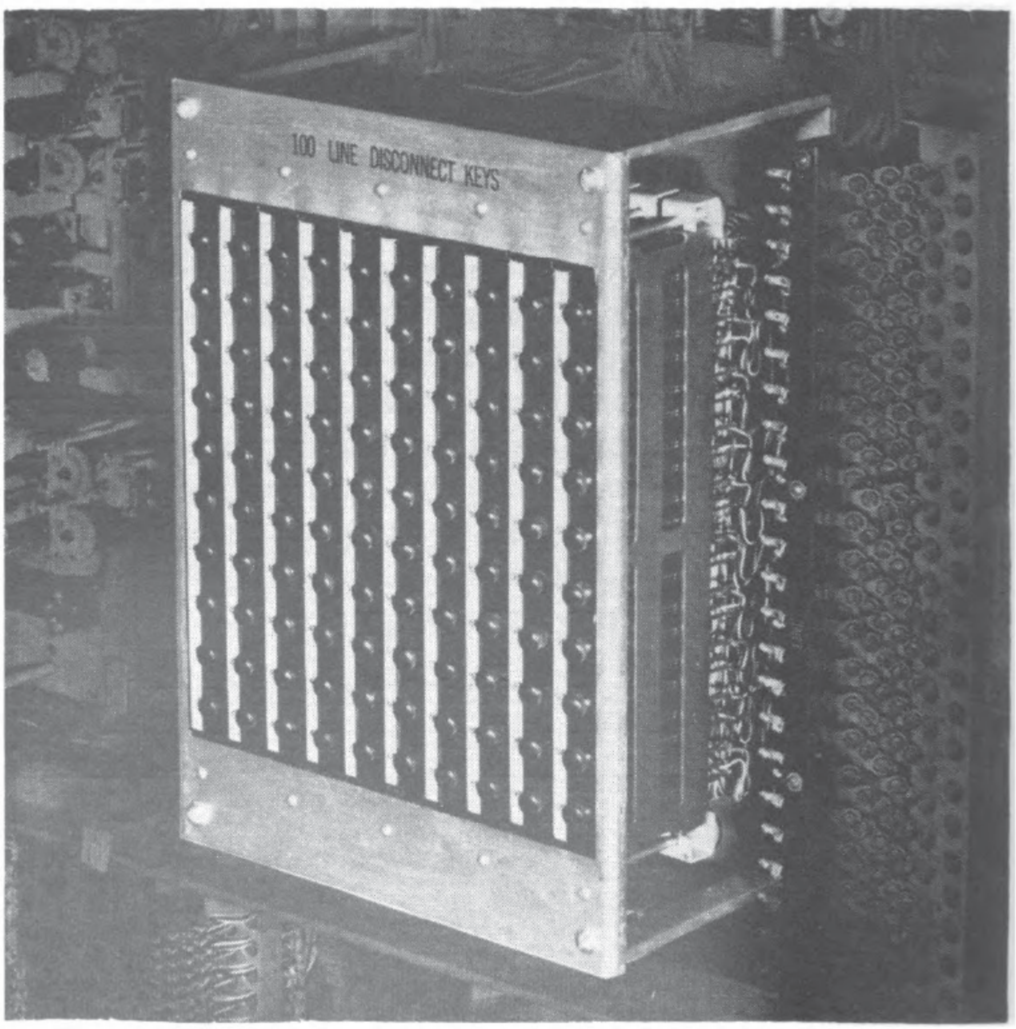


Figure 12—7.—Line disconnect key panel.

The line disconnect key can be locked in the OPEN position by inserting a cotter pin in the hole provided in the key shaft. This locking arrangement can be used to prevent ring-back tone from being returned to the calling station when the line disconnect key is associated with an unassigned line.

Hand Test Telephone

The hand test telephone, as previously mentioned, is mounted on the rear of the finder board by a spring clamp. The hand test telephone can be used independently or in conjunction with the test set, depending on the type of tests to be conducted.

The hand test telephone (fig. 12–8) consists of a conveniently shaped handle with a transmitter at one end,

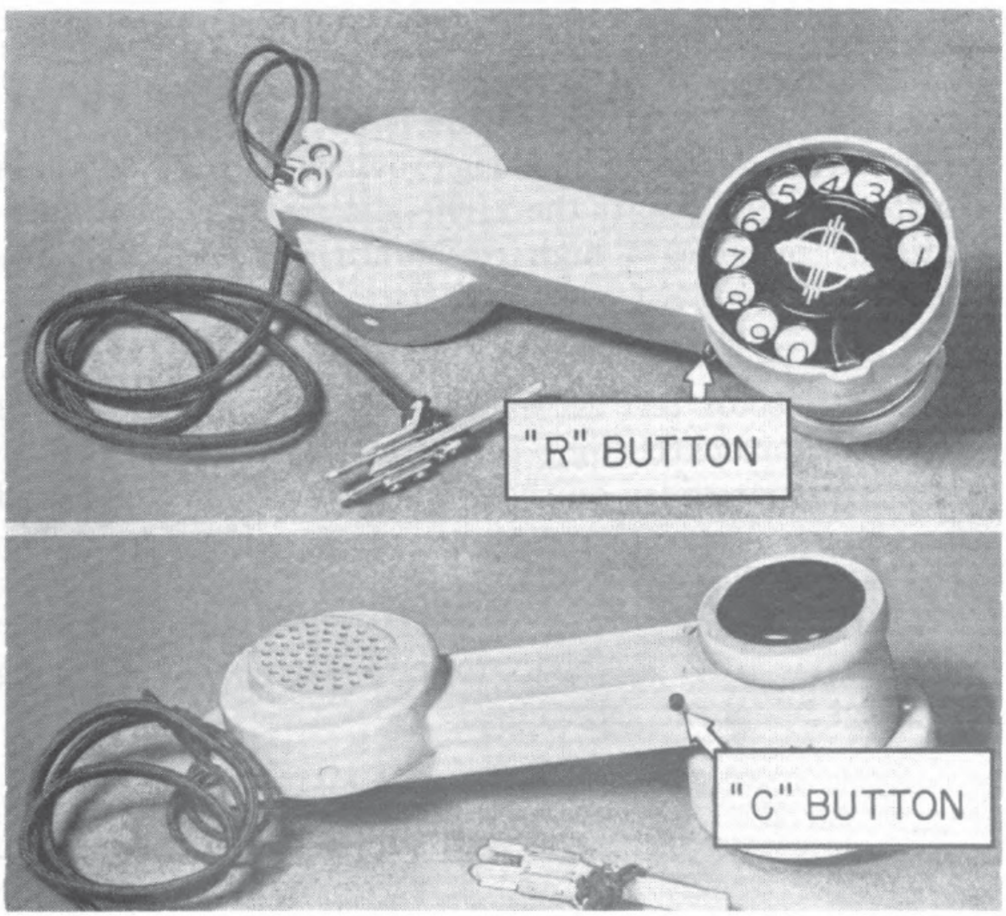


Figure 12—8.—Hand test telephone.

and a receiver and dial placed back-to-back at the other end. A 2-conductor test cord with a test plug is connected to the transmitter end of the case. Two push switches marked *C* and *R* respectively are externally located on opposite sides of the handle toward the receiver end. A capacitor, an impedance coil, and a resistor are mounted inside the case.

When push switch *C* is depressed, a capacitor is connected in the transmitter circuit. The capacitor cuts off the talking circuit to permit listening only, and also prevents interference with the dial pulses when plugging in the hand test telephone. Push switch *C* is released when dialing up the switch being tested, or, if the switch is already in use, when using the hand test telephone to talk to either party.

When push switch *R* is depressed, a 1,200-ohm resistor is connected in series with the transmitter. This resistor is used sometimes to test the operation of Strowger switches. However, this button is not used normally because the hand test telephone is provided with a 1,000-ohm resistor (in addition to the 1,200-ohm resistor) that automatically provides a high resistance in series with the line when testing Strowger switches.

Connector Test Set

The connector test set is jack-mounted on the rear of the connector board (fig. 11–6) and can be moved readily to the space provided on the front of the connector board (fig. 11–5) for testing the group A connectors. The patching cord, used in connection with the test set, is coiled in loops and stowed on brackets located on the rear of the finder board, adjacent to the space provided for the hand test telephone (fig. 11–2).

CONNECTOR TEST SET CIRCUIT

The connector test set circuit (fig. 12–9) is designed to be used for weekly routine testing of connectors and for weekly call-through tests of finders and connectors.

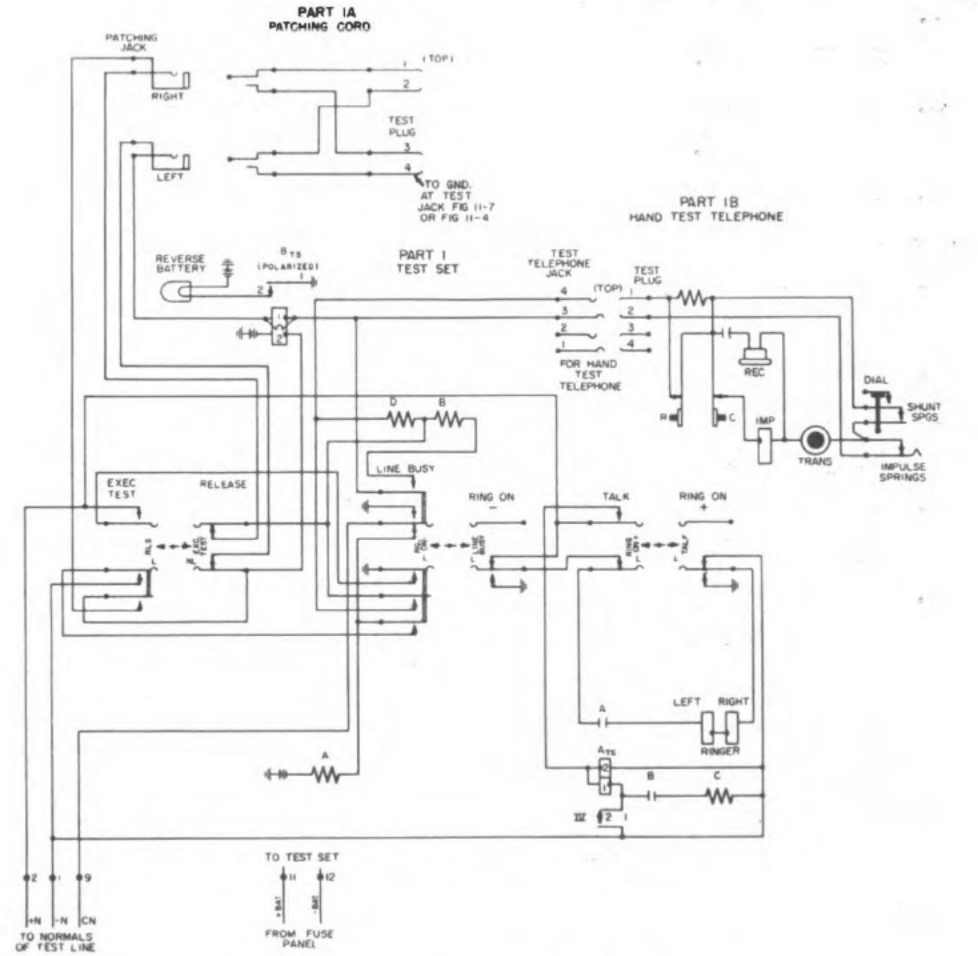


Figure 12—9.—Connector test set circuit.

Functions

The connector test set circuit:

A. Routine testing of connectors.

1. Seizes the connector to be tested.
2. Transmits the impulses from the hand test telephone to the connector under test.
3. Tests the ringing circuits of the connector for ringing on either side of the line.
4. Tests the ring cutoff in the connector.
5. Tests the transmission battery circuit of the connector.
6. Tests the reverse battery supervision in the connector.

7. Tests the action of a connector when it encounters a busy line.
8. Tests the executive right-of-way feature of special connectors.
9. Tests release of the connector under test.

B. Weekly call-through test.

1. Check the (two) group A and group B finder control switches for normal operation.
2. Check the operation of the distributor relays.
3. Check every free finder for normal operation and stepping.
4. Check the finder cut-through relay (*C*6) for proper operation.
5. Check the continuity of circuits between finders and connectors.

The connector test set cannot be used to conduct trunk hunting tests because the telephone system has only one test line (29), and a trunk hunting group includes more than one line.

Routine Connector Test

Seizing the Connector to be Tested.—When testing a connector, the TEST PLUG of the hand test telephone is inserted in the TEST TELEPHONE JACK (part 1B of fig. 12–9) to prepare a d-c loop over which the switch under test can be dialed. The patching cord is used to connect the associated patching jack (part 1A of fig. 12–9) to the test jack of the connector to be tested.

The test jack of the connector under test (fig. 11–7) places ground on lead 4 of the test plug (part 1B of fig. 12–9). This ground completes the circuit to winding 2 of relay B_{ts} in the test set (part 1 of fig. 12–9). However, relay B_{ts}, which is a polarized relay, does not operate on its winding 2.

The connector under test is seized by the hand test telephone (part 1B of fig. 12–9) through the d-c loop over leads 1 and 2 of the TEST PLUG. The connector under test places negative battery on lead 1 and ground on lead 2

through relay A_c in the connector (fig. 11–7). This action energizes winding 1 of relay B_{ts} (part 1 of fig. 12–9). Windings 1 and 2 of relay B_{ts} set up opposing magnetic fields to prevent relay B_{ts} from operating at this time.

Monitoring Before Dialing.—When monitoring calls through a busy switch, push switch C on the hand test telephone (part 1B of fig. 12–9) is depressed to open the loop circuit through the transmitter without interrupting the transmission circuit to the receiver. If the test plug is now placed in the test jack of the connector there will be no interference with the conversation through this switch. The test operator can hear the conversation through the telephone receiver but cannot talk to the parties on the connection. If the operator desires to talk, push switch C is released to complete transmission battery.

Dialing the Connector Under Test.—The connector under test is now dialed from the hand test telephone. If the connector is functioning properly, the dial impulses cause the connector under test to step the shaft and wipers to the dialed number. The action is similar to that described under Dialing the Called Line in chapter 11.

Seizing the Test Line.—If the number dialed is that of the test line (line 29 in this system), and if the connector is functioning properly, the connector will switch through to the test line as a result of negative battery through the 1,200-ohm called line relay resistor A on the CN lead of the test line.

Ringing the Test Line.—The test line is now rung by the connector over the + N and − N leads causing the ringer of the test set to operate. This action tests the connector to determine if it is ringing the called line properly and returning ring-back tone to the calling line. The ring-back tone should now be heard in the receiver of the test telephone.

To ring the + side of the line, the positive RING ON key is operated (part 1 of fig. 12–9). This action causes the connector to complete ringing current to the + N lead,

completing the circuit to the test set ringer from + N through the RINGER and capacitor A to ground. The action is similar to that described under Ringing the Dialed Station in chapter 11.

This test is used to check the ringing, to determine if the connector is ringing the called line properly, and if the ringing is on the correct side of the line.

Testing the Connector for Ring Cutoff, Battery Reversal, and Transmission.—To test a connector for ring cutoff after the test line has been rung, the TALK key corresponding to the hookswitch of the called telephone is operated. This action completes the loop through winding 2 of relay A_{ts} across the + N and − N leads to the ring cutoff relay, F_c, in the connector. Relay F_c should operate and open the circuit to the RINGER. The operation of relay D_c reverses battery to the calling lines (leads 1 and 2 of the test plug). Relay F_c should also remove ring-back tone to the test telephone.

The reversal of battery on leads 1 and 2 of the TEST PLUG reverses the magnetic field set up by winding 1 of relay B_{ts}. Relay B_{ts} now operates because the magnetic fields set up by windings 1 and 2 aid each other.

RELAY B_{ts} OPERATES:

1. Contacts 1–2 complete the circuit to the reverse battery lamp to light this lamp.

When the reverse battery lamp is lighted, it indicates that battery reversal has occurred.

Ground and negative battery on the + N and − N leads respectively complete the circuit to winding 2 of the simulated talk relay A_{ts} (talk key operated). The talk key in the test set performs a function similar to that of the hookswitch of the called telephone.

RELAY A_{ts} OPERATES:

1. Contacts 1–2 close its (relay A_{ts}) winding 1 in parallel with winding 2. The opposing fields of these windings cause relay A_{ts} to restore. Contacts 1–2 open winding 1, and relay A_{ts} again operates.

RELAY A_{ts} continues to operate and restore from transmission battery and ground over the + N and — N leads. This action generates a (simulated talking) tone at its contacts, and if the transmission is functioning properly, this tone is carried through the connector under test over leads 1 and 2 of the TEST PLUG to the hand test telephone where it can be heard.

Releasing the Connecter Under Test.—To release the connector under test, the d-c loop circuit through the hand test telephone and the circuit to winding 2 of relay B_{ts} are opened by operating the EXECUTIVE TEST RELEASE key (corresponds to the hookswitch of the calling telephone) to the release position. This action releases the connector (under test) which returns to normal. Relay B_{ts} also restores because its windings 1 and 2 have been opened.

RELAY B_{ts} RESTORES:

1. Contacts 1–2 open the circuit to the reverse battery lamp to extinguish this lamp.

The circuit to relay A_{ts} is opened when the connector returns to normal and the connector comes to rest in a non-operated position. The circuit is now at normal.

Leak and Busy Test.—To determine if the connector under test will function properly when there is a leak of 10,000 ohms across the dialing line and when it encounters a busy line, the LINE BUSY key (part 1 of fig. 12–9) is operated prior to dialing the test line. This action replaces the 1200-ohm negative battery resistor A on the CN lead with positive ground, making the test line busy, and completes a circuit through the 10,000-ohm resistor, B, across the leads of the hand test telephone. This key also shunts out the 1000-ohm calling line loop resistor, D.

The test line number is again dialed to determine if the connector under test will function from a line shunted by 10,000 ohms. If the switch is functioning properly, it will not be stepped to the dialed line (test line). Because the test line is now busy, the connector should return busy

tone to the test telephone and should not ring the test line.

To test the connector for defects that cause it to seize a busy line when it becomes free, the LINE BUSY key is restored. This action removes ground from, and places negative battery on, the CN lead. If the connector is defective, it will cut through (at this time) to the formerly busy line.

The TALK key is operated to determine if the connector has cut through. If the connector has cut through, the tone will be heard in the hand test telephone.

Executive Right-Of-Way Test.—To test the executive right-of-way feature of a connector, the LINE BUSY key is operated before dialing the test line. The busy tone should now be heard in the hand test telephone. The EXECUTIVE TEST key is operated to cause the connector to switch through to the busy line. This action completes the circuit to the executive relay, L_c, to remove busy tone and to cut-in on the busy station.

To test the connector transmission circuit, the TALK key is now operated and relay A_{ts} should vibrate (operate and restore from ground and negative battery on the + N and − N leads) to send out the simulated talk tone. The TALK key is then restored to remove simulated talk tone and to prepare the ringing circuit.

To determine if the connector functions properly when the called line becomes free, the LINE BUSY key should be restored to remove the busy ground and to replace it with negative battery. If the connector is functioning properly it should now switch through as a normal call and ring the test line. The TALK key should again be operated for transmission test.

Release From the Executive Right-Of-Way Test.—To release the switch under test from the executive right-of-way test, the EXECUTIVE TEST RELEASE key and the LINE BUSY key are operated to their RELEASE positions to return the switch and test set circuit to normal.

Call-Through Test

The following operating procedure is correct for using the connector test set for conducting a complete call-through test.

1. Plug patching cord in the connector under test and in the connector test set.
2. Depress push switch *C* on the hand test telephone and plug in the connector test set.
3. Monitor the connector under test (to determine if the connector is preseized) and if free, operate the connector BUSY key.
4. Release push switch *C* on the hand test telephone and listen for dial tone.
5. Operate the positive RING ON key.
6. Dial 229 and listen for ring and ring-back.
7. Operate the TALK key.
8. Listen for ring and ring-back to be cut off, listen for simulated talk tone, and determine that the reverse battery lamp lights.
9. Operate the release key.
10. Observe that the connector restores.
11. Restore all keys.
12. Listen for dial tone.
13. Operate the LINE BUSY key.
14. Dial 929.
15. Listen for busy tone.
16. Restore the BUSY key and listen for busy tone.
17. Reoperate the BUSY key.
18. Operate the EXECUTIVE key and listen for busy tone to be cut off.
19. Operate the TALK key, listen for simulated talk tone and determine that the reverse battery lamp does not light.
20. Restore the TALK key.
21. Restore the BUSY key and operate the negative RING ON key.
22. Listen for ring and ring-back tone.

23. Operate the TALK key.
24. Listen for simulated talk tone and determine that the reverse battery lamp lights.
25. Restore the TALK key and determine that the reverse battery lamp is extinguished and that simulated talk tone stops.
26. Restore all keys on the test set.
27. Depress push switch *C* on the hand test telephone and determine that the connector restores.
28. Disconnect the patching cord from the connector and plug into the next free connector.

The foregoing procedure will be followed in testing the next connector.

QUIZ

1. What is the purpose of the dial telephone alarm system?
2. What two types of signals comprise the dial telephone alarm system?
3. Give an example of an immediate alarm.
4. Give an example of a delayed alarm.
5. What is the function of the timer relays?
6. Where are the alarm lamps located for the dial telephone system?
7. What two troubles are indicated by the power fail alarm?
8. What condition is indicated by the power fuse alarm?
9. What three troubles are indicated by the motor-generator fail alarm?
10. What type of alarms are the power fail, power fuse, and motor-generator fail alarms?
11. What condition is indicated by the switchboard fuse alarm?
12. What conditions are indicated by the (1) connector release and (2) finder release alarms?
13. How is a faulty (off-normal) finder switch located?
14. What troubles are indicated by the finder blocked alarm?
15. Why is the busy key operated on the correspondingly numbered connector when the defective finder has been located?

16. What is the connector permanent condition?
17. What two conditions are indicated by the ringing machine fail alarm?
18. What immediate action should be taken when the ringing machine fail alarm operates?
19. What is the purpose of the common alarm buzzer?
20. Name the three types of tones supplied by the ringing machine in addition to the regular ringing current.
21. What is the function of the ringing interrupter springs?
22. What is the function of the busy interrupter springs?
23. What is the function of the timer interrupter springs?
24. What starts and stops the ringing machine that is in service?
25. What is the purpose of the ringing machine test key?
26. What is the function of the supervisory control and alarm relays mounted on the finder board?

REFERRING TO FIGURE 12–4 FOR QUESTIONS 27 THROUGH 50:

27. When considering the timer relay rules, which odd relay must be considered as an even relay?
28. When considering the timer rules, what three actions occur when an odd relay operates?
29. When considering the timer rules, what action occurs when an odd relay releases?
30. When considering the timer rules, what action occurs when an even relay operates?
31. When considering the timer rules, what action occurs when an even relay releases?
32. Which timer relay remains operated at all times during the operation of the timers?
33. What completes the operating circuit to relay *T*13?
34. What opens the holding circuit to relay *T*4?
35. What completes the operating circuit to relay *T*5?
36. What completes the operating circuit to relay *T*6?
37. Where does ground originate to operate the ringing machine?
38. What shunts relay *RC*1?
39. What completes the circuit to start the ringing machine?

40. What opens the operating circuit to relay *RC*2?

41. What completes the busy tone circuit to the connector?

42. What completes the dial tone circuit to the connector?

43. What is the purpose of the rectifier in the circuit of relay *RM*2?

44. What is the purpose of resistor B in the rectifier circuit of relay *RM*2?

45. What breaks the ringing current into codes?

46. What completes the circuit to the ringing machine fail lamp, 1 or 2?

47. What completes the circuit to the ringing machine audible alarm?

48. When the motor-generator in the power equipment fails, what completes the operating circuit to the motor-generator failure relay, *CS*1?

49. What opens the operating circuit to relay *CS*3?

50. What opens the operating circuit to relay *C*S2?

REFERRING TO FIGURE 12–6 FOR QUESTIONS 51 THROUGH 66:

51. What leads supply the interrupted (busy) tone current and ground from the ringing machine control relay (parts 2 and 4 of fig. 12–4) to the tone distribution circuit?

52. Where does ground originate to complete the operating circuit to relay *FB*9 (part 9 of fig. 11–4)?

53. What removes busy tone from the AFB lead (fig. 11–4)?

54. What leads supply continuous (dial) tone current and ground from the ringing machine control relays (parts 2 and 4 of fig. 12–4) to the tone distribution circuit (part 1 of fig. 12–6)?

55. What completes the operating circuit to relay R2 in the finder release circuit?

56. In the finder release circuit, what completes the operating circuit to relay *T*14 to start the timer?

57. What completes the operating circuit to relay *R*4 in the finder release circuit?

58. What completes the lock circuit of relay *R*4 in the finder release circuit?

59. What opens the lock circuit to relay *R*4 in the finder release circuit?

60. What opens the operating circuit to relay $R3$ in the finder release circuit?

61. What completes the operating circuit to relay $R1$ in the finder and connector release circuit?

62. What completes the operating circuit to relay $P1$ in the connector permanent alarm circuit?

63. What completes the operating circuit to winding 1 of relay $P2$ in the connector permanent alarm circuit?

64. Where does ground originate for the lock circuit of relay $P2$ in the connector permanent alarm circuit?

65. What opens the operating circuit to relay $P2$ in the connector permanent alarm circuit?

66. What opens the A and AG leads to the buzzer in the connector permanent alarm circuit?

67. Name the four components that comprise the dial telephone testing equipment.

68. How many line disconnect keys are mounted on the line disconnect key panel in the 100-line dial telephone system?

69. What three conditions require the use of line disconnect keys?

70. What action occurs when push switch C (provided with the hand test telephone) is depressed?

71. What action occurs when push switch R (provided with the hand test telephone) is depressed?

72. What is the purpose of the connector test set?

73. What type of connector test cannot be accomplished by use of the connector test set?

74. What is the test number in the 100-line telephone system?

75. Why is push switch C depressed on the hand test telephone when monitoring calls through a busy switch?

76. What function does the talk key perform in the test set?

77. What is the working name of relay A_{ts}?

78. What function does the executive test release key perform in the test set?

79. What opens the circuit to the reverse battery lamp?

CHAPTER 13

DIAL TELEPHONE POWER AND ACCESSORY EQUIPMENT

POWER EQUIPMENT

The dial telephone power equipment supplies all of the electrical energy necessary for the operation of the automatic switchboard. This equipment consists of a motor-generator, a storage battery, a motor starter, and a power panel. The motor-generator and storage battery are connected in parallel and supply the 48-volt d-c power to operate the switchboard equipment.

Motor-Generator

Two motor-generators are usually provided in order to have one unit in stand-by for an emergency. These units are never operated in parallel. The primary purpose of the motor-generator is to charge the storage battery. However, the motor-generator can be operated continuously to carry the switchboard load and at the same time to trickle-charge the battery.

A-C MOTOR.—The a-c motor is a 1.5 hp., wound-rotor type induction motor. It is supplied from the ship's 3-phase, 60-cycle, 120-volt power.

D-C GENERATOR.—The d-c generator is a self-excited, 2-pole compound generator with diverter poles that are located midway between the main poles. The series

windings on the diverter poles are wound in such a direction as to produce the same polarity as that of the associated main poles. Each diverter pole is connected to a main pole by a magnetic bridge.

A longitudinal slot in each bridge near the associated diverter pole causes the iron to be easily saturated around the slots. As the load on the generator increases, the series ampere-turns increase. But the bridge is saturated, therefore, more flux is diverted from the bridge into the armature in direct proportion to the load. Hence, the output voltage in the d-c generator is controlled by shunting more or less of the main flux away from the armature by means of this magnetic bridge.

When the load is increased on the diverter-pole generator, the leakage flux is diverted into the armature from the magnetic bridge so that the main pole is not saturated as in the additive compound generator. This action results in a linear voltage characteristic for the diverter-pole type of generator.

The diverter poles also have the advantage of providing a flux of the correct polarity along the brush axis for aiding commutation; hence, they act like commutating poles. However, because they are aligned with the brush axis, they do not contribute directly to the generated emf of the armature, but indirectly by diverting flux from the bridge.

A reversal of current in the series turns cannot cause a reversal of flux in the main field because the restricted section of the bridge limits the flux that can pass through it. Unlike the straight compound type, this generator will not run away when it accidentally motors (battery drives the generator as a motor) because the shunt field predominates at all times.

Motor Starter

The motor starter is a magnetic across-the-line starter that provides for low-voltage release and overload protection. The motor-generator is started by closing the

motor-generator input switch, thereby causing the line contactor to connect the motor across the line. When the line voltage drops below a predetermined value, the line contactor disconnects the motor from the line. When the voltage is restored to normal, the line contactor closes and connects the motor to the line. When an overload occurs, the overload contacts open and deenergize the line contactor that disconnects the motor from the line. To restart the motor, the overload contacts must be reset manually.

Power Panel

The power panel (fig. 13–1) includes the necessary apparatus for controlling the operation of the motor-generators. This apparatus consists of (1) control relays, (2) a voltmeter, (3) a generator ammeter, (4) a battery ammeter, (5) generator field rheostats, (6) a voltmeter switch, (7) a generator switch, (8) two motor-generator input switches, (9) a generator output switch, and (10) fuses.

The VOLTMETER is provided with a 3-position switch. When this voltmeter switch is in the NORMAL position, the voltmeter indicates the battery voltage. When the switch is operated to the generator volts position, 1 or 2, the voltmeter indicates the output voltage of the associated generator.

The GENERATOR AMMETER indicates the output load current of the generator.

The BATTERY AMMETER indicates the current to or from the storage battery to indicate the rate of charge or discharge of the battery.

The GENERATOR SWITCH is a 3-position switch provided for selecting the generator that is to be cut in. When this switch is in the NORMAL position, the generator circuits are open. When the switch is operated to the generator position, 1 or 2, it prepares the circuit to the control relays.

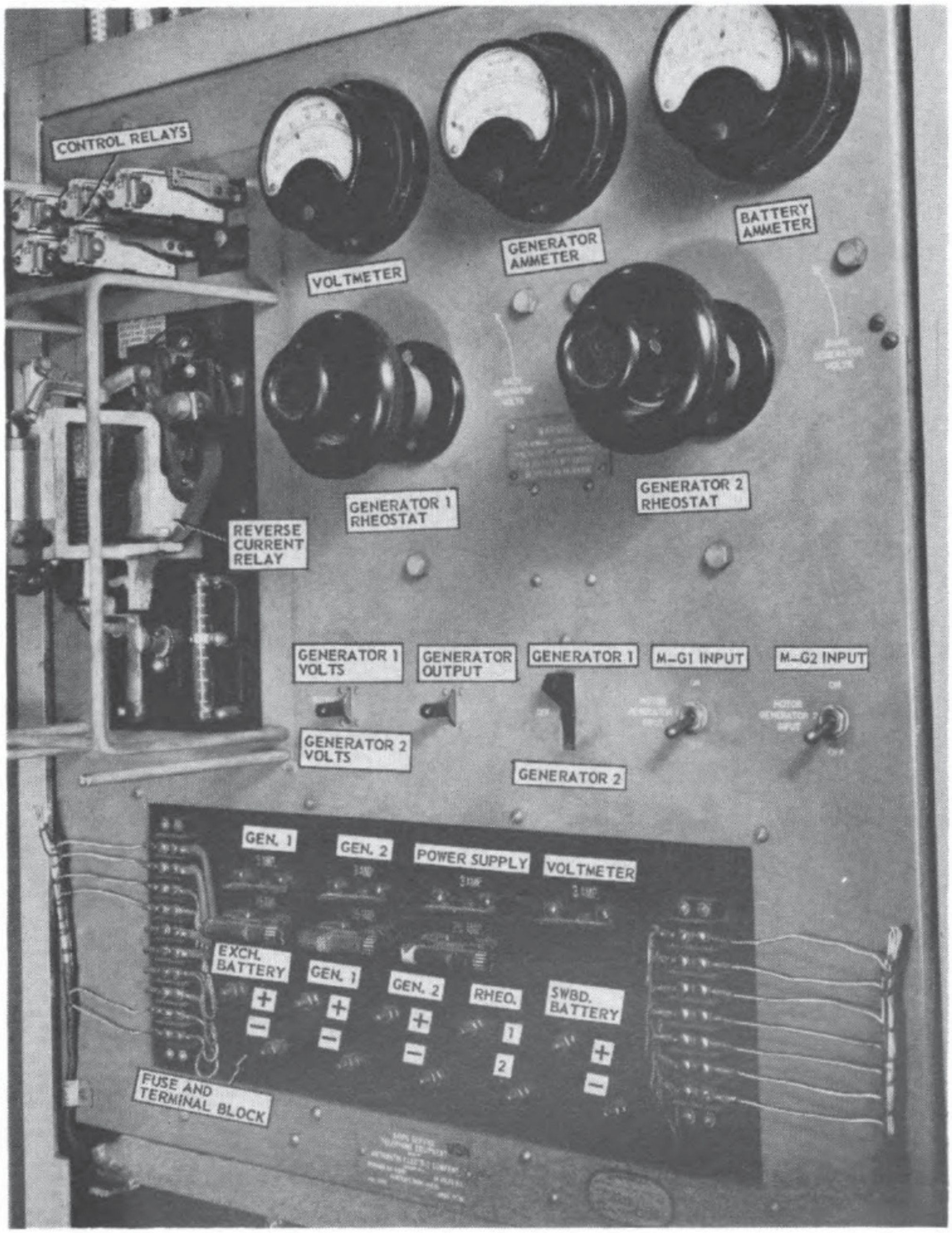


Figure 13—1.—Power panel.

The MOTOR-GENERATOR INPUT SWITCHES (one for each motor-generator) are ON-OFF toggle switches. These input switches are provided to select the motor-generator that is to be placed in service.

The GENERATOR OUTPUT SWITCH is a 2-position toggle switch. This switch is operated momentarily to cut in

the generator and place the generator output in parallel with the battery and the switchboard load.

The FUSES are mounted on the front of the power panel and are designated according to use and ampere rating. All of these fuses, except the voltmeter fuse, are of the cartridge type with a corresponding 3-ampere alarm type (indicating) fuse in parallel. When one of the cartridge fuses blows, its associated alarm fuse also blows to close the alarm circuit. The voltmeter fuse is simply a 3-ampere cartridge fuse that does not sound an alarm when it blows.

The supervisory alarms described with the alarm system are provided for the power equipment. These include the power fail, power fuse, and motor-generator fail alarms.

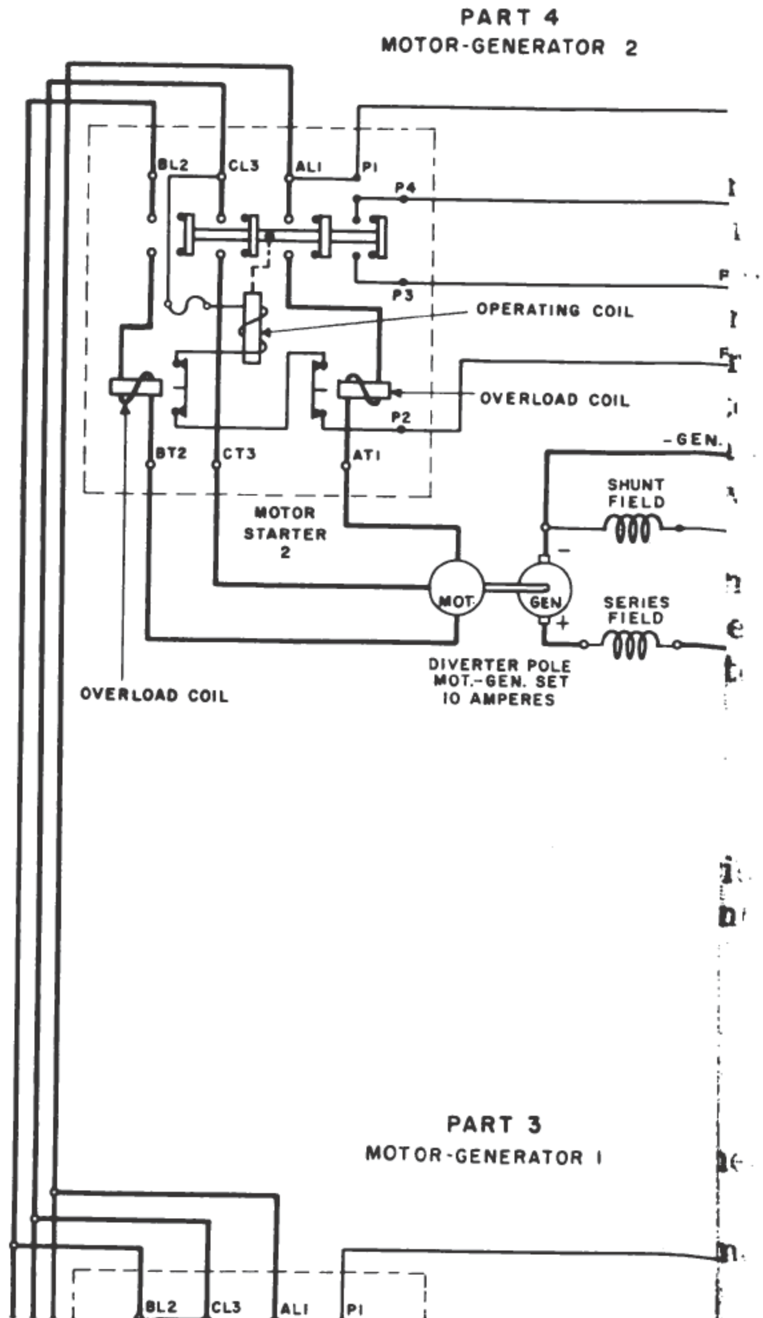
POWER CIRCUIT

The power circuit (fig. 13–2) is designed to provide for the supervision and control of the power equipment of a dial telephone system.

Functions

The power circuit provides for:

1. Manual control of the automatic motor-generator starter switch.
2. Cutting in the motor-generator under manual control.
3. Indication of the battery and generator voltage.
4. Manual cut in after failure of a motor-generator.
5. Sounding of an alarm if a motor-generator fails.
6. Measuring of the generator output current.
7. Measuring of the charge or discharge current of the battery.
8. Sounding of an alarm when the power fuses are blown.
9. A-c alarm supply.



PART 4
MOTOR-GENERATOR 2
BL2
CL3
AL1
P1
P4
P3
OPERATING COIL
OVERLOAD COIL
P2
BT2
CT3
AT1
-GEN.
SHUNT FIELD
MOTOR STARTER 2
MOT.
GEN.
SERIES FIELD
DIVERTER POLE MOT.-GEN. SET 10 AMPERES
OVERLOAD COIL
PART 3
MOTOR-GENERATOR 1
BL2
CL3
AL1
P1

PAGE NOT AVAILABLE

In the operation of the battery-charging equipment, the voltage at the automatic switchboard must not exceed 56 volts. However, the common battery voltage is 48 volts. The generator output is adjusted to 51.6 volts by a field rheostat. This setting of the rheostat is not changed, except to occasionally overcharge or equalize the battery cells. If it becomes necessary to charge the battery at a higher rate than usual, the generator voltage is set so that the maximum voltage that can be applied to the switchboard is 56 volts.

Starting the Motor-Generator

MOTOR-GENERATOR INPUT SWITCH.—The motor-generator input switch, 1 or 2 (part 1 of fig. 13–2), is operated to the ON position to start the selected motor-generator. This action connects together the P1 and P2 leads, and completes the circuit from the CFR lead to the + GEN leads. The P1–P2 connection completes the circuit to the operating coil (solenoid) of the associated motor starter (part 3 or 4 of fig. 13–2) across the AL1 and CL3 leads of the ship's 3-phase, 120-volt power.

MOTOR-GENERATOR INPUT SWITCH 1 OPERATED (MANUALLY):

1. Completes a circuit on the CFR lead to bring in an alarm if needed.
2. Completes the operating circuit to the solenoid of the across-the-line starter.

The motor starter operates and connects the AL1, CL3, and BL2 power leads to the starter terminals, *AT*1, *CT*3, and *BT*2, respectively. The circuit to the motor is completed and the motor-generator starts.

MOTOR STARTER SWITCH OPERATES:

1. Completes the ship's 3-phase supply to the motor.
2. Prepares the operating circuit to the reverse current relay.

VOLTMETER SWITCH.—The voltmeter switch is operated to the generator volts position, 1 or 2 (depending on which motor-generator was started), to determine the generator

voltage. The generator voltage should be greater than the battery voltage before cutting in the generator.

GENERATOR SWITCH.—The generator switch is operated to the generator position, 1 or 2 (depending on which generator is to be cut in), to prepare the circuits to relays *PC*6 and *PC*5 (part 1 of fig. 13–2).

The generator cannot be cut in before the generator voltage builds up to 40 volts because the reverse-current relay (*PC*6) will not operate before this voltage is attained. When relay *PC*6 has operated and placed the generator output in parallel with the battery and the switchboard load, this relay will remain operated until a reverse current of 10 amperes flows through its series coil.

CUTTING IN THE GENERATOR.—The generator output switch (part 1 of fig. 13–2) is operated momentarily to cut in the generator. This action completes the circuit from the + GEN lead, to the P3 lead, through the motor starter (operated position), to the P4 lead, through the right-hand section of the generator switch (operated position), through the generator output switch, through relay *PC*5, through resistor *E* and the series coil of relay *PC*6, to the left-hand section of the generator switch (operated position), and to the — GEN lead.

RELAY *PC*5 IS OPERATED:

1. Contacts 1–2 complete the circuit to the shunt coil of relay *PC*6 in series with resistor *SR* and the series coil of *PC*6.
2. Contacts 3–4 complete its (relay *PC*5) lock circuit and short circuit the contacts of the generator output switch.

Resistor SR is adjusted so that if the generator voltage is 40 volts or more, relay *PC*6 will operate on its series and shunt coils in series.

The generator output switch is now manually released, opening a multiple circuit to relay *PC*5.

RELAY *PC*6 OPERATES (ON 40 VOLTS):

1. Main contacts complete the − GEN lead to the multiple connection of the − EXCH BAT and − SWBD BAT leads through the series coil.
2. The auxiliary shunt contacts open the circuit across resistor *PR* so that resistors *PR* and *SR* are in series with its (relay *PC*6) shunt coil.
3. The auxiliary contacts complete the operating circuit to relay *PC*4 in series with resistor *E* across the + and − GEN leads.

RELAY *PC*4 OPERATES:

1. Contacts 1–2 open the circuit from the CFR lead to the + GEN lead.
2. Contacts 3–5 complete a multiple circuit to the shunt coil of relay *PC*6.
3. Contacts 4–5 open the circuit to relay *PC*5.

RELAY *PC*5 RESTORES:

1. Contacts 1–2 open a multiple circuit to the shunt coil of relay *PC*6.
2. Contacts 3–4 open part of its incomplete circuit.

The motor-generator now starts charging the battery and carrying the switchboard load.

Stopping the Motor-Generator

The motor-generator is stopped by operating the motor-generator input switch to the OFF position before cutting out the generator (generator switch operated). This action restores relays *PC*6 and *PC*4.

RELAY *PC*6 RESTORES:

1. Main contacts open the − GEN lead from the − EXCH BAT lead and the − SWBD BAT lead in multiple through the series coil (charging circuit).
2. Auxiliary shunt contacts complete a short circuit across resistor *PR*.
3. Auxiliary contacts open the operating circuit to relay *PC*4.

RELAY *PC*4 RESTORES:

1. Contacts 1–2 prepare the circuit from the CFR (alarm) lead to the + GEN lead. Under normal conditions of restoring an alarm is not sounded because the motor-generator input switch is opened before relay PC4 restores. This action opens the CFR (alarm) lead connection to the + generator bus at the motor generator input switch before contacts 1–2 of relay PC4 (restored) can complete the alarm circuit.
2. Contacts 3–5 open the circuit to the shunt coil of relay *PC*6.
3. Contacts 4–5 prepare a circuit to relay *PC*5.

The generator switch is then operated to the NORMAL position.

The motor-generator is now cut out and is stopped. The unit can be shut down during periods of light load, but when it is restarted, the normal output voltage of 51.6 volts should not be altered by adjusting the field rheostat.

Motor-Generator Failure

If the generator voltage should fall below the battery voltage while the generator is cut in (relays *PC*6 and *PC*4 operated), a current will flow from the battery in the reverse direction through the series coil of relay *PC*6, which is in series with the generator. When the reverse current reaches a value of 10 amperes, the magnetic field of the series coil opposes that of the shunt coil sufficiently to cause relay *PC*6 to restore.

RELAY *PC*6 RESTORES:

1. Main contacts open the – GEN lead from the – EXCH BAT lead and the – SWBD BAT lead in multiple through its series coil (charging circuit).
2. Auxiliary shunt contacts complete a shunt circuit to resistor *PR*.
3. Auxiliary contacts open the operating circuit to relay *PC*4.

RELAY *PC*4 RESTORES:

1. Contacts 1–2 complete ground (+ GEN) on the CFR lead.
2. Contacts 3–5 open the hold circuit to the shunt coil of relay *PC*6.
3. Contacts 4–5 prepare a circuit to relay *PC*5.

The motor-generator is now cut out but continues to operate with no load on the generator. After a predetermined time delay, an alarm will automatically sound and a light will indicate the trouble. The voltage of the motor-generator is noted by operating the voltmeter switch to the appropriate position. If the voltage is over 40 volts, the motor-generator can be cut in, as previously described. On the other hand, if the voltage is under 40 volts and fails to build up, the other motor-generator can be started and the generator cut in, as previously described.

Overloads on the Ship's A-c Power

The motor starter is provided with two overload coils connected in series with the AT1 and BT2 leads. Contacts associated with the overload coils control the circuit to the operating coil of the motor starter. When an overload condition occurs in either the AT1 or BT2 leads, the corresponding overload coil assembly operates.

OVERLOAD COIL ASSEMBLY OPERATES:

1. Opens the circuit to the operating coil of the motor starter.

MOTOR STARTER RELEASES:

1. Contacts *AL*1, *BL*2, and *CL*3 open the circuit to the motor and the overload coil assemblies.
2. Contacts *P*3 and *P*4 open the hold circuit to relay *PC*6 and the motor stops.

TO RESTART THE MOTOR:

1. Operate the motor-generator input switch to the OFF position.
2. Reset the overload coils manually.
3. Operate the motor-generator input switch to the ON position.

MOTOR STARTER OPERATES:

1. Completes the circuit to the motor and the overload coil assemblies.
2. The motor starts.

When the ship's a-c power is restored after temporary failure, the motor will start automatically but the generator will not cut in until the generator output switch is reoperated manually. If it is desired to have the generator automatically resume operation when the power is restored after temporary failure, the contacts of the nonlocking generator output switch can be shunted.

Switchboard Battery Failure

Normally, relay *PC*2 is held operated by the exchange battery or the generator voltage, or both. If both of these sources fail to keep the SWBD BAT voltage above a predetermined value, or if the power supply fuse is blown, the circuit to relay *PC*2 is opened.

RELAY *PC*2 RESTORES:

1. Contacts 3–4 complete the circuit to the buzzer over the A and AG leads.
2. Contacts 1–2 complete the circuit to the power fail lamp over the A and AG leads.

When the A lead is connected to the AG lead and to the AB lead through the power fail lamp, the audible alarm is sounded in the ring and tone machine, timer, and alarm circuits, and the power fail lamp is lighted (part 1 of fig. 13–2).

When the voltage returns to normal, relay *PC*2 will reoperate to cut off the power fail alarm.

Delayed Alarms

GENERATOR NOT CUT IN.—If a motor-generator is started but is not cut in, positive generator voltage on the + GEN lead through contacts 1–2 of relay *PC*4 that is restored will remain on the CFR lead. This positive voltage (ground) on the CFR lead completes a circuit to relay *CS*1 (part 8 of fig. 12–4) in the ring and tone machine,

timer, and alarm circuits to cause an audible and visual alarm signal after a predetermined delay.

GENERATOR FAILS AFTER CUT IN.—If the motor-generator fails after it is cut in, a positive voltage (ground) is placed on the CFR lead through the 1–2 contacts of relays *PC*1 and *PC*4. This condition causes an audible and visual alarm signal in the ring and tone machine, timer, and alarm circuits after a predetermined delay.

Fuse Alarms

GENERATOR FUSES.—The — GEN leads from each motor-generator are protected by a 15-ampere charging fuse and a 3-ampere (grasshopper) alarm fuse in multiple. When these fuses blow, the alarm fuse completes the circuit (broken arrow, part 1 of fig. 13–2) to relay *PC*1 across the GEN leads, and the generator is cut off from the switchboard and battery circuits.

RELAY *PC*1 OPERATES:

1. Contacts 1–2 open the CFR lead.
2. Contacts 3–4 complete the circuit to the buzzer over the A and AG leads.
3. Contacts 5–6 complete the circuit to the power fuse lamp over the A and AB leads.

When the A lead is connected to the AG lead and to the AB lead through the power fuse lamp, the audible alarm is sounded in the ring and tone machine, timer, and alarm circuits, and the power fuse lamp is lighted.

When the charging fuse blows, relays *PC*6 and *PC*4 restore, disconnecting the motor-generator from the battery and switchboard circuits and restoring the circuit to normal, as previously described under the section on Stopping the Motor-Generator. When the generator fuse is replaced, the circuit is open to relay *PC*1.

RELAY *PC*1 RESTORES:

1. Contacts 1–2 complete the circuit from the CFR lead to the + GEN leads.
2. Contacts 3–4 open the circuit to the buzzer from the A lead to the AG lead.

3. Contacts 5–6 open the circuit to the power fuse lamp from the A lead to the AB lead.

This action stops the power fuse alarm. If the generator is not cut in again, the generator fail alarm will be sounded, as previously described.

POWER SUPPLY FUSES.—The — BAT lead is protected by a power fuse and a 3-ampere (grasshopper) alarm fuse in multiple. When these fuses blow, the alarm fuse completes the circuit to relay *PC*3 across the exchange battery, and the power supply is cut off from the switchboard equipment.

RELAY *PC*3 OPERATES:

1. Contacts 1–2 complete the circuit to the power fuse lamp over the A and AB leads.
2. Contacts 3–4 complete the circuit to the buzzer over the A and AG leads.

When the A lead is connected to the AG lead and to the AB lead through the power fuse lamp, the audible alarm is sounded in the ring and tone machine, timer, and alarm circuits, and the power fuse lamp is lighted.

When the power supply fuse is replaced, the circuit is opened to relay *PC*3.

RELAY *PC*3 RESTORES:

1. Contacts 1–2 open the circuit from the A lead to the AB lead through the power fuse alarm.
2. Contacts 3–4 open the circuit to the buzzer from the A lead to AG lead.

This action stops the power fuse alarm.

ACCESSORY EQUIPMENT

The dial telephone accessory equipment includes an attendant's cabinet that is used to establish calls to and from shore exchanges when the ship is in port. The attendant's cabinet is interposed between the automatic switchboard (in the ship) and the shore exchange by means of two-way trunks to the automatic switchboard and two-way trunks to the shore exchange. The cabinet is

provided with a dial telephone so that connection can be made with an automatic or a manual shore exchange.

Attendant's Cabinet

The attendant's cabinet for a 100-line system (fig. 13–3) consists of a steel enclosure designed for bulkhead mount-

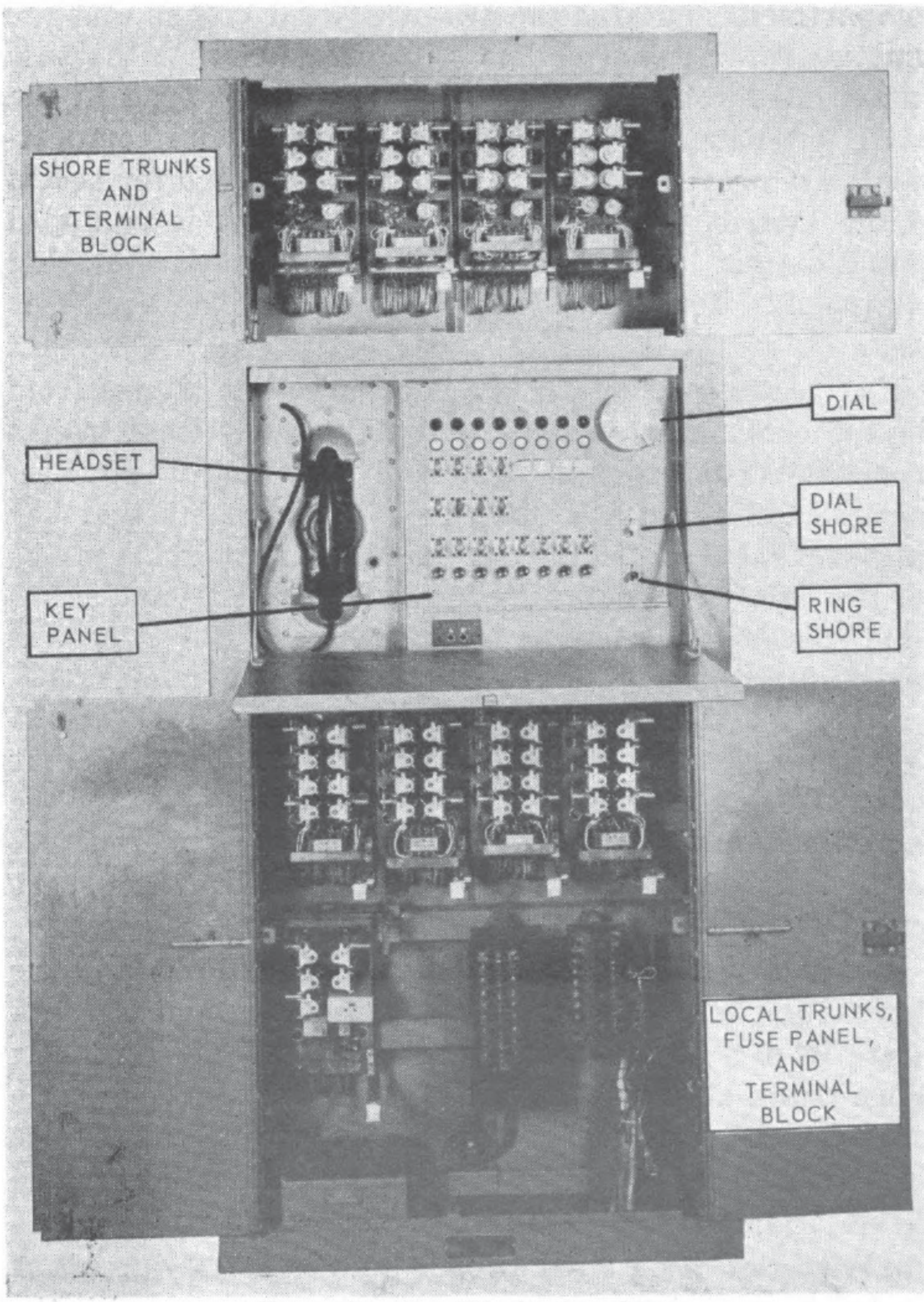


Figure 13—3.—Attendant's cabinet.

ing. The cabinet is divided into three compartments. The top compartment contains the two-way shore-line trunks and the terminal block. The center compartment contains the key panel, the handset, and the dial. A jack is provided for plugging in the headset. The bottom compartment contains the two-way local trunks and the equipment for the attendant's telephone circuit, the fuse panel, the terminal block, and a headset (stored in the lower left-hand corner). The top and bottom compartments are provided with two hinged doors each for access to the interiors. The center compartment is equipped with a hinged door for access to the attendant's operating equipment. This door swings forward to form a shelf or desk.

KEY PANEL.—The four two-way shore-line trunks from the top compartment and the four two-way local trunks from the bottom compartment each terminate in four associated lamp and key strips. The four lamp and key strips for the local trunks and the four lamp and key strips for the shore-line trunks are located on the left- and right-hand sides respectively of the key panel. The lamp and key strip for each local trunk contains a busy lamp (red), a call lamp (white), two shore trunk (cross-connecting) keys, a talk (answering) key, and a release key. Similar equipment is contained on the lamp and key strips for the shore-line trunks, except for the double-throw shore trunk keys. The final connections are established by the shore trunk keys located only on the local trunk strips.

The wiring of the local and shore-line trunks and the shore trunk keys is indicated by the single-line diagram in figure 13–4. As previously mentioned, two double-throw shore trunk keys are provided on each of the four lamp and key strips of the associated two-way local trunks. The upper shore trunk key has two positions designated TRUNK 1 and TRUNK 2, and the lower shore trunk key has two positions designated TRUNK 3 and TRUNK 4. All of the trunk 1 positions are connected in parallel with the

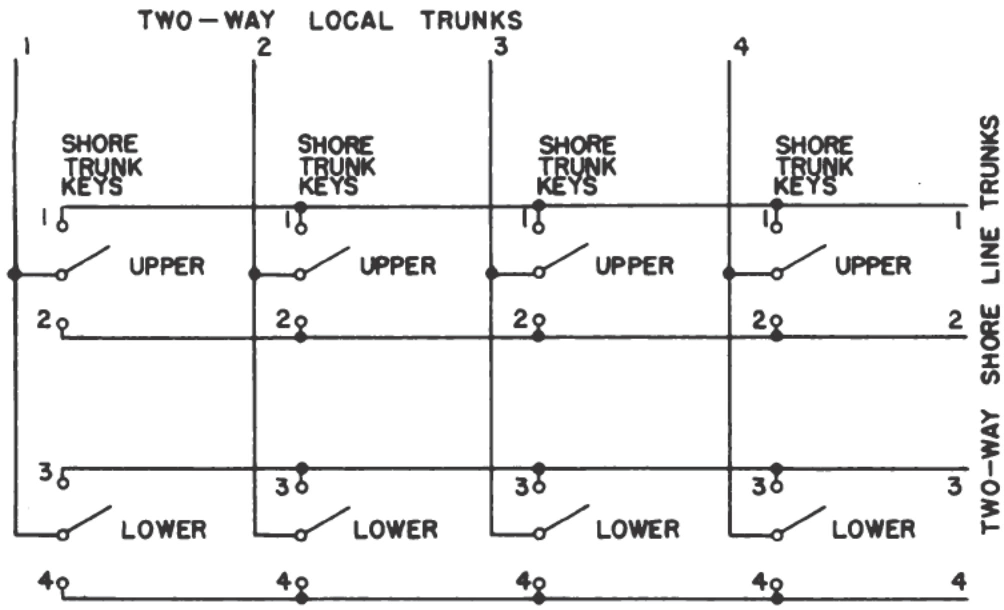


Figure 13-4.—Shore trunk key connection schematic.

shore-line trunk 1; all of the trunk 2 positions are connected in parallel with the shore-line trunk 2; and so on for the remaining key positions and shore-line trunks. The local trunk 1 is connected in parallel with the upper and lower shore trunk switches, so that local trunk 1 can be connected to either the trunk 1 or trunk 2 position by the upper shore trunk key or to either the trunk 3 or trunk 4 position by the lower shore trunk key. The remaining local trunks, 2, 3, and 4, are each similarly connected to an upper and lower shore trunk key. Hence, any local trunk can be cross connected with any shore-line trunk, and vice versa. However, when a cross-connecting key and any local trunk is operated to a certain number, the local trunk is associated with the correspondingly numbered shore-line trunk. Hence, only one cross-connecting key should be operated to the same number at any one time.

A push-switch type release key is provided for each trunk. By means of the release keys, the attendant can release either end of a connection while holding the other end.

A dial shore key and a ring shore key are located on the right of the trunk strips below the dial.

When a call is received on the local or shore-line trunks the corresponding CALL lamp lights and the common buzzer sounds. When the attendant answers by operating the TALK key, the CALL lamp is extinguished, the buzzer is silenced, and the BUSY lamp is lighted. When a shore line disconnects, no action occurs. However, when the local station disconnects, the local CALL lamp lights again, the BUSY lamp remains lighted, and the buzzer sounds to signal the attendant. Thus, the two lamps provide CALL, BUSY, and DISCONNECT indications with an audible signal on the CALL and DISCONNECT indications. A shore-line DISCONNECT signal is not provided because of the many and varied types of shore exchanges that might be involved. However, the attendant is provided with a means for dialing over both the local and shore-line trunks, and for ringing on the shore-line trunk if the shore exchange employs a ringing magneto and local battery telephones.

HEADSET.—During busy periods the headset can be used by the attendant instead of the handset. When the headset is plugged into the jack located at the bottom of the panel, the transmitter and receiver are in the attendant's telephone circuit at all times, and the attendant can converse on any trunk that has the TALK key operated.

When the headset is plugged in (or the handset is removed) and any TALK key is operated, the buzzer will not sound to interrupt the attendant, but the lamps will function as usual to provide the required signals. However, the buzzer will sound if the attendant attempts to leave without answering all new calls and releasing all completed calls.

Shore-Line Control Switch

Each local trunk is associated with a line circuit (line relay) on the automatic switchboard. These line circuits can be used for regular local (shipboard) service when they are not being used for shore-line service. The shore-line control switch, mounted on the lamp and key

panel, is provided to switch the attendant's cabinet in and out of service.

Shore-Line Fuse and Protector Box

A shore-line fuse and protector box is provided to protect the line equipment and the attendant from injury that can be caused if the shore lines are subjected to lightning discharges and/or crosses with power circuits. The protective apparatus comprises eight fuses and eight lightning arresters contained in a watertight enclosure designed for bulkhead mounting. The arrester affords a ready path to ground when lightning or high-potential discharges are impressed on the line. The fuse will blow and open the line when the line current exceeds the rated capacity of the fuse.

The positive and negative leads of each shore line are connected to the respective shore-line terminals on the shore-line fuse and protector box. Each shore-line lead is connected in common to one end of a fuse and an arrester block. The positive and negative leads of the attendant's cabinet are connected to the respective attendant-cabinet terminals on the shore-line fuse and protector box. The opposite ends of the arrester blocks are connected to the bonding cable outside of the box. The free end of the bonding cable is bolted to the bulkhead and both ends are soldered to ensure a good ground. The arrangement for one telephone circuit is illustrated in the schematic diagram (fig. 13–5).

Shore-Line Connection Box

The positive and negative leads of each shore line from the shore-line fuse and protector box are connected to two watertight shore-line connection boxes. Each box has a capacity for four shore lines. One box is located on both the port and starboard sides of the ship. This arrangement facilitates connecting the shore-line cables into the ship from either the port or starboard side when the ship is in port.

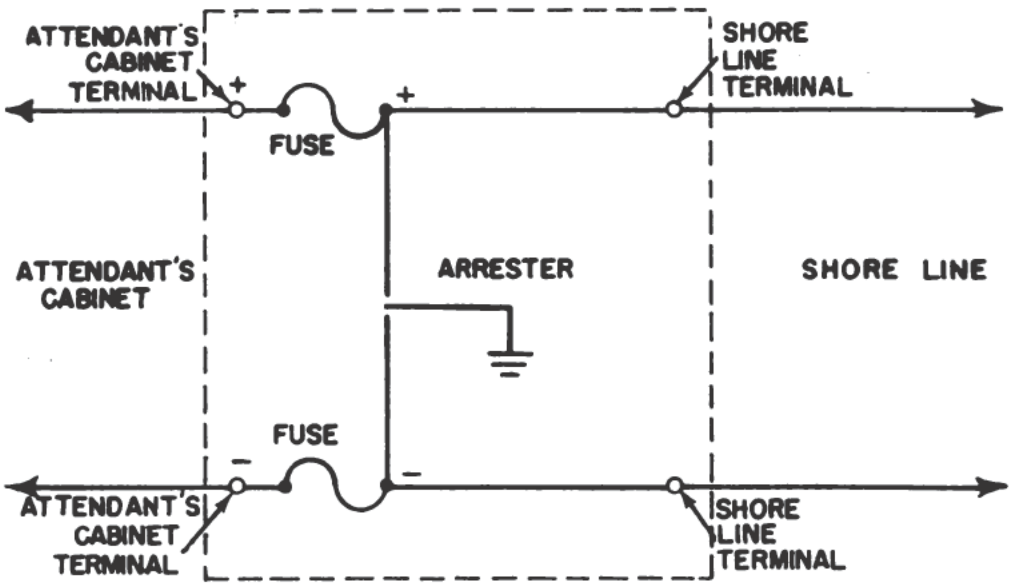


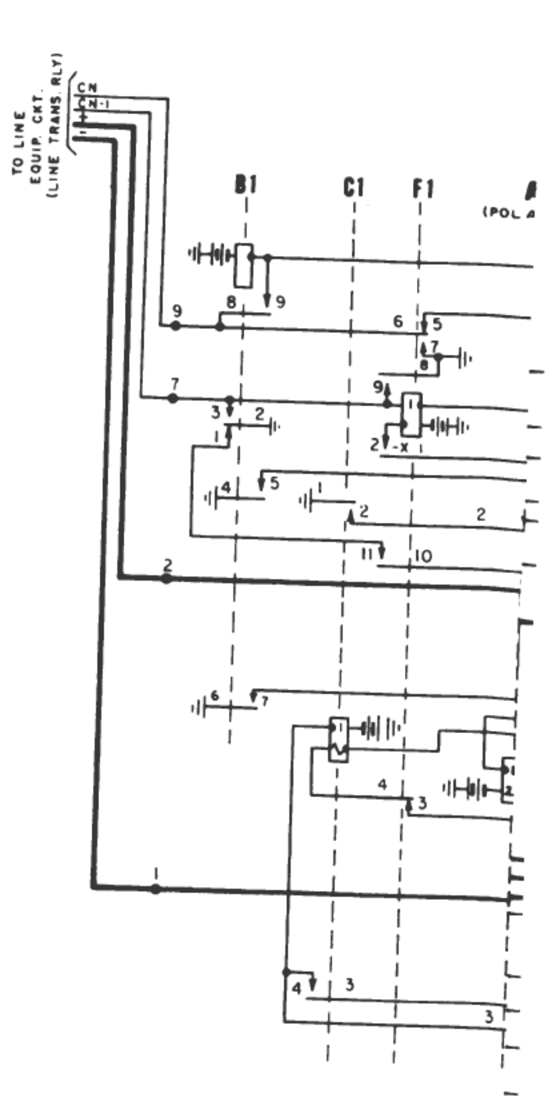
Figure 13—5.—Shore-line fuse and lightning-arrester circuit.

ATTENDANT'S CABINET SHORE-LINE CIRCUIT

The attendant's cabinet shore-line circuit (fig. 13–6) is designed to provide two-way traffic through a cordless attendant's cabinet between the ship's dial telephone system (PAX) and a manual, automatic, or magneto shore exchange.

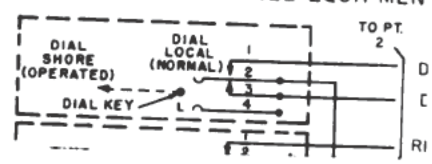
The working names of the relays in the attendant's cabinet of the 100-line system are:

*A*1 and *C*1 . . . Second traffic control relays
*B*1 . . . . Negative battery for relay M_c (auxiliary relay)
*D*1 . . . . Local trunk holding relay
*E*1 . . . . Local dial transfer relay
*F*1 . . . . Signal relay (guard relay)
*G*1 . . . . Attendant's cabinet local hookswitch relay
*H*1 . . . . Traffic control relay (used with relay F1)
*AT*1 . . . . Buzzer cutout relay
*AT*2 . . . . Replaces shorting out contacts of the dial



PART 3B

ATTENDANT'S PANEL EQUIPMEN



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*AT*3 .... Transmission battery for attendant
*A*1 .... Polarized relay
*A*4 .... Shore dial transfer relay
*B*4 .... Shore hookswitch relay
*C*4 .... Ring relay
*D*4 .... Auxiliary ring relay
*E*4 .... Ring shore relay (code ring)
*F*4 .... Shore trunk holding relay
AR .... Buzzer relay
RET ....Retard coil (no contacts) used as a filter with capacitor E
*RC*1 and *RC*4 . Repeater coils (1 to 1 transformer to isolate the shore exchange from attendant's cabinet)

Functions

On ship-to-shore calls the attendant's cabinet shore-line circuit performs the following functions:

1. Signals the attendant when a local trunk is seized by a connector in the ship's exchange.
2. Connects the attendant's telephone to the local trunk when the attendant answers.
3. Seizes a two-way shore-line trunk when the attendant extends the call.
4. Makes both trunks busy to other calls.
5. Rings or dials the shore exchange.
6. Signals the attendant when the calling party disconnects.

On shore-to-ship calls the attendant's cabinet shore-line circuit performs the following functions:

1. Signals the attendant when the two-way shore-line trunk is seized by an incoming call.
2. Connects the attendant's telephone to the shore-line trunk when the attendant answers.
3. Seizes a two-way local trunk when the attendant extends the call.
4. Makes both trunks busy to other calls.

5. Dials the called number of the ship's exchange.
6. Signals the attendant when the called party disconnects.

Ship-to-Shore Calls

The two-way local trunk (part 1 of fig. 13–6) is prepared for shore line service by operating the shore line control switch (part 1D of fig. 11–4) on the lamp and key panel to the ON position. This action completes the operating circuit to the line transfer relay *LT* (part 1B of fig. 11–4), to prepare the trunk for calls TO and FROM the ship when in port. The lines aboard ship that are designated for use with the attendant's cabinet are lines 37, 38, 39, and 30. When the associated line transfer relays operate, they transfer these lines from the ship's exchange to the attendant's cabinet and make these numbers trunk hunting. These four lines can now be used only for calls between the ship and shore.

SEIZURE OF THE TRUNK.—When a line station aboard ship desires to make a call to shore and dials the attendant's cabinet number, (trunk hunting group 37, 38, 39, or 30), ground is placed on the CN lead by the connector to complete the circuit to relay *B*1 (part 1 of fig. 13–6) and make the trunk available to the connector. This action is described in the connector circuit of the finder connector link in chapter 11 (fig. 11–7).

RELAY *B*1 OPERATES:

1. Contacts 2–3 place ground on the CN1 lead, a shunting ground on winding 1 of relay *F*1, and complete the operating circuit to relay *L*2 of line 37 which is the first telephone in this group.
2. Contacts 4–5 complete an operating circuit to the call supply lamp (part 2) through relay *AR*3.
3. Contacts 6–7 complete the operating circuit to winding 1 of relay *H*1.
4. Contacts 8–9 complete its (relay *B*1) first lock circuit.

RELAY *AR*3 OPERATES:

1. Contacts 1–2 complete the circuit to the night alarm buzzer through the windings of the retard coil, *RET*, which is used as a filter with capacitor *E* for the night alarm buzzer.

RELAY *H*1 OPERATES:

1. Contacts 2–3 and 5–6 prepare a d-c loop for relay F_c in the connector.
2. Contacts 8–9 complete the first hold circuit for relay *L*2 of line 37, and a partial operating circuit for relay *F*1. However, relay *F*1 is shunted at this time.
3. Contacts 10–11 prepare a ground for the operating circuit of relay *F*1.
4. Contacts 12–13 prepare its lock circuit.

ATTENDANT ANSWERS.—The local trunk remains in this condition, with the call supply lamp lighted, and the buzzer operating until the attendant answers by removing the handset and operating the local TALK key (part 2 of fig. 13–6) associated with the local call supply lamp and the local trunk.

LOCAL TALK KEY (PART 2) OPERATED:

1. Contacts 1–2 complete an operating circuit to relay *G*1.
2. Contacts 3–4 complete an operating circuit to relay *AT*1 (part 3 of fig. 13–6).
3. Contacts 5–6 and 7–8 prepare the talking circuit between the repeater coil, *RC*1, and the attendant. This circuit is over the T lead through the attendant's handset, over the R lead through contacts 7–8 of the local TALK key, through the repeater coil, RC1, and back over the T lead to contacts 5–6 of the local talk key.
4. Contacts 9–10 prepare a circuit to winding 1 of relay *E*1 by way of the D1 and D leads.

RELAY *AT*1 OPERATES:

1. Contacts 1–2 remove a multiple operating ground from the night alarm buzzer.

RELAY $G1$ OPERATES:

1. Contacts $1T$–$2T$ open the operating circuit of relay $B1$.
2. Contacts $4T$–$5T$ complete the lock circuit to relay $H1$.
3. Contacts $6T$–$7T$ complete its own first lock circuit, and also the circuit to winding 2 of relay $A1$ over the R1 lead, through contacts 3–4 of the local release key, over the R2 lead, to ground.
4. Contacts $1B$–$2B$ open the operating circuit to the call supply lamp and to relay $AR3$.
5. Contacts $2B$–$3B$ prepare a circuit to the call supply lamp.
6. Contacts $4B$–$5B$ complete the talking circuit between the calling party and the repeater coil, $RC1$, and the partial operating circuit to relay F_c in the connector. The talking circuit is from the negative lead over the L2 lead, through contacts 1–2 of the local release key, over the L1 lead, through repeater coil, $RC1$, to the positive lead.
7. Contacts $6B$–$7B$ complete a circuit to the local trunk BUSY lamp.

Relay $A1$ will not operate on its winding 2 alone because it is a polarized relay, and both windings must be energized in the same direction for it to operate.

RELAY $AR3$ RESTORES (ITEM 4 ABOVE):

1. Contacts 1–2 remove an operating ground from the night alarm buzzer (part 3).

ATTENDANT'S HANDSET HOOKSWITCH (PART $3B$) OPERATED:

1. Contacts 1–2 complete the talking circuit over the L1 and L2 leads between the calling party and the attendant and completes the receiver circuit from the L1 to the L2 leads.
2. Contacts 3–4 complete the operating circuit to relay $AT3$. This circuit is from winding 1 over the L3 lead, to contacts 3–4 of the hookswitch, the

transmitter, lead L1, winding 1–2 of the induction coil, and to winding 2 of relay *AT*3.

RELAY *AT*3 OPERATES:

1. Contacts 1–2 open an incomplete circuit to the night alarm buzzer.

The attendant can now talk with the calling station to ascertain the desired number.

EXTENDING THE CALL TO A SHORE-LINE TRUNK.—The attendant now operates one of the shore-line trunk (cross-connecting trunk keys 1, 2, 3, or 4) keys on the same local trunk strip to seize an idle shore trunk. For example, the upper shore trunk key is operated to the position designated TRUNK 1. Also, the attendant operates the correspondingly numbered shore trunk on the shore-line trunk strip to the position designated SHORE TRUNK 1.

SHORE TRUNK KEY 1 (PART 2) OPERATED:

1. Contacts 1–2 complete the operating circuit from ground over the MR lead to relay *D*1.
2. Contacts 3–4 and 5–6 extend the talking circuit to the repeater coil, *RC*4, in the shore-line trunk. This circuit is from the local trunk, over the T lead, through contacts 3–4 of the shore trunk key 1, over the T lead to the shore-line trunk, and over the R lead, through contacts 5–6 of the shore trunk key 1, and back over the R lead, to the local trunk.
3. Contacts 7–8 complete the operating circuit to relay *F*4 over the MR lead.

RELAY *D*1 OPERATES:

1. Contacts 1–2 open the first lock circuit to relay *G*1.
2. Contacts 2–3 complete the second lock circuit to relay *G*1.

RELAY *F*4 OPERATES:

1. Contacts 2–3 prepare a lock circuit to relay *B*4.

SHORE TALK KEY (part 2) OPERATED:

1. Contacts 1–2 complete the operating circuit over the CR lead to winding 1 of relay *B*4.

2. Contacts 3–4 place a multiple ground on relay *AT*1 (part 3) over the TG lead.
3. Contacts 5–6 and 7–8 extend the talking circuit from the repeater coil, *RC*4, in the shore-line trunk to the attendant (part 3B of fig. 13–6). The local and shore trunk multiple circuit is from the local trunk (part 1), over the T lead, through contacts 3–4 of the shore trunk key 1 (part 2), over the T lead to the shore-line trunk (part 4), through the repeater coil, *RC*4, over the R lead, through contacts 5–6 of the shore trunk key 1, out over the R lead, to the local trunk, and through the repeater coil, *RC*1. The attendant's handset circuit is over the T lead, to contacts 5–6 of the local TALK key (connected to contacts 5–6 of the shore TALK key), through contacts 3–4 of the shore trunk key 1, over the T lead, to the shore-line trunk 1, through the repeater coil, *RC*4, back over the R lead, through contacts 7–8 of the shore TALK key (connected to contacts 7–8 of the local TALK key), over the R lead, to the attendant's handset.
4. Contacts 9–10 prepare the operating circuit to winding 1 of relay *A*4 over the D1 lead.
5. Contacts 11–2 prepare the operating circuit to relay *E*4 over the RR lead.

RELAY *B*4 OPERATES (ITEM 1 SHORE TALK KEY OPERATED):

1. Contacts 2–3 complete its lock circuit over the R1 lead, through the shore release key, over the R2 lead, through contacts 1–2 of relay *F*4, to ground.
2. Contacts 4–5 prepare a talking circuit from the repeater coil, *RC*4, in the shore-line trunk to the called party, and complete a loop circuit across the + L and − L leads.
3. Contacts 6–7 complete the circuit to the shore-line BUSY lamp associated with the shore-line trunk 1.

LOCAL TALK KEY RESTORED:

1. Contacts 1–2 open the operating circuit to winding 1 of relay *G*1 over the CR lead.
2. Contacts 3–4 open the operating circuit to relay *AT*1 (part 3) over the TG lead.
3. Contacts 5–6 and 7–8 open a multiple talking circuit between the repeater coil, *RC*1, and the attendant.
4. Contacts 9–10 open an incomplete circuit to winding 1 of relay *E*1 over the D1 lead.

If the shore exchange is the automatic (common-battery) type, completing the loop to the shore trunk seizes the automatic equipment and prepares it for dialing.

If the shore exchange is the manual (common-battery) type, completing the loop to the shore trunk signals the operator.

If the shore exchange is the magneto (local-battery) type, the attendant momentarily operates the ring shore key. No supervision will be received from the magneto office.

RING SHORE KEY (PART 3*B*) OPERATED:

1. Contacts 1–2 complete the operating circuit to relay *E*4 over the RR lead, through contacts 11–12 of the shore TALK key (part 2).
2. Contacts 3–4 complete the circuit to the ringing machine over the MST lead.

RELAY *E*4 OPERATES:

1. Contacts 1–2 open the negative lead of the repeater coil, *RC*4.
2. Contacts 2–3 complete ringing to the negative shore line lead.
3. Contacts 4–5 open the positive lead of the repeater coil, *RC*4.
4. Contacts 5–6 provide a return path for the ringing current.

Thus, the ringing current is sent out over the line to the magneto exchange to signal the operator. When the

ring shore key is restored to normal, the ringing ceases and relay $E4$ releases.

The dial key must be operated to the SHORE position before dialing. Each time the dial is rotated off normal, contacts 2–3 of the dial off-normal (D.O.N.) springs complete the operating circuit to relay $AT2$ (part 3) over the D1 lead.

If the shore exchange is the automatic type, closing the loop when relay $B4$ operates will complete a circuit to a line relay ashore and result in the attendant getting dial tone from a shore connector.

DIAL SHORE KEY (PART 3B) OPERATED:

1. Contacts 1–2 prepare the operating circuit to the pulsing relay, $A4$, over the D1 lead through contacts 9–10 of the shore TALK key.
2. Contacts 2–3 further open a circuit to relay $E1$.

DIAL OPERATED:

1. Contacts 2–3 of the dial off-normal springs complete an operating circuit to relay $AT2$.

RELAY $AT2$ (PART 3) OPERATES:

1. X contacts (1–2) short circuit the receiver of the attendant's handset to prevent loud clicks while he is dialing.
2. Contacts 4–5 complete a short circuit across the talking circuit between the repeater coils, $RC1$ and $RC4$.
3. Contacts 6–7 complete the operating circuit to relay $A4$ from contacts 1–2 of the dial switch over the D1 and D leads.

RELAY $A4$ OPERATES:

1. Contacts 1–3 and 4–6 connect the positive and negative shore line leads to the dialing circuit.
2. Contacts 2–3 and 5–6 remove the repeater coil, $RC4$, from the dialing loop to eliminate its shunting effect on this circuit.

DIAL RESTORES:

1. The dial impulses are sent out over the positive and negative shore line leads to the automatic shore exchange which steps a connector ashore.
2. Contacts 2–3 of the dial off-normal springs open the circuit to relays *AT*2 and *A*4, which restore.

RELAY *AT*2 (PART 3) RESTORES:

1. X contacts (1–2) short circuit the receiver of the attendant's receiver.
2. Contacts 4–5 open the short circuit on the repeater coil, *RC*4.
3. Contacts 6–7 further open the incomplete circuit to relay *A*4 from the dial switch over the D and D1 leads.

RELAY *A*4 RESTORES:

1. Contacts 1–3 and 4–6 open the dialing circuit.
2. Contacts 2–3 and 5–6 prepare the talking circuit from the repeater coil, *RC*4, to the shore exchange.

DIAL SHORE KEY RESTORED:

1. Contacts 1–2 further open a circuit to relay *A*4.
2. Contacts 3–4 prepare the local dialing circuit over the D lead.

After the last digit has been dialed, the attendant restores the dial key to NORMAL. The switches at the automatic shore exchange test the called line. If the line is found busy, the switches return busy tone and if the line is found free, the switches start automatic ringing and return ring-back tone. When the called party answers, automatic ringing is stopped and the transmission circuit is completed between the called line and the trunk. The attendant can now retire from the connection by restoring the shore TALK key associated with the shore-line trunk and the local TALK key, if not already released as previously explained.

SHORE TALK KEY (PART 2) RESTORED:

1. Contacts 1–2 open the operating circuit to relay *B*4 over the CR lead.

2. Contacts 3–4 open the hold circuit to relay $AT1$ (part 3) over the TG lead.
3. Contacts 5–6 and 7–8 open the attendant's talking circuit.

Relay $AT1$ (part 3) restores:

1. Contacts 1–2 prepare an incomplete circuit to the night alarm buzzer (part 3A).

Attendant's handset hookswitch (part 3B) restored:

1. X contacts (1–2) open the circuit to the receiver.
2. Contacts 3–4 open the circuit to relay $AT3$.

Relay $AT3$ restores:

1. X contacts 1–2 prepare an incomplete circuit to the night alarm buzzer.

The talking circuit is complete between the calling party and the called party, and the attendant's talking circuit is disconnected.

RELEASE.—The release of the connection is controlled by both the calling party and the attendant (relays $B1$, $H1$, $G1$, $D1$, $B4$, and $F4$; and one shore trunk key operated). When the calling party releases, ground is removed from the CN lead, thereby opening the operating circuit to relay $B1$.

RELAY $B1$ RESTORES:

1. Contacts 1–2 prepare a circuit to the call supply lamp (part 2) over the LL lead and to relay $AR3$ over the A lead.
2. Contacts 2–3 remove the shunt from relay $F1$.
3. Contacts 6–7 open the operating circuit to relay $H1$.
4. Contacts 8–9 open its (relay $B1$) lock circuit.

RELAY $F1$ OPERATES:

1. X contacts (1–2) complete its (relay $F1$) lock circuit through contacts 10–11 of relay $H1$ to ground.
2. Contacts 3–4 open the circuit of winding 2 of relay $C1$, which is across capacitor B in the $RC1$ repeater coil circuit.

3. Contacts 5–6 further open the operating circuit to relay $B1$.
4. Contacts 6–7 place ground on the CN lead to keep this line relay busy.
5. Contacts 8–9 place ground on the CN1 lead to keep the line relay operated.
6. Contacts 10–11 complete the second operating circuit to the call supply lamp (part 2) through contacts $2B$–$3B$ of relay $G1$ over the LL lead, and to relay $AR3$ over the A lead.

RELAY $AR3$ OPERATES:

1. Contacts 1–2 complete a circuit to the night alarm buzzer.

The call supply lamp and night alarm buzzer give the attendant release supervision. The attendant now restores the shore TRUNK key associated with the proper call supply lamp.

SHORE TRUNK KEY RESTORED:

1. Contacts 1–2 open the operating circuit to relay $D1$ and the lock circuit to relay $G1$.
2. Contacts 3–4 and 5–6 open the talking circuit between the repeater coils, $RC1$ and $RC4$.
3. Contacts 7–8 open the operating circuit to relay $F4$, and the lock circuit to relay $B4$.

RELAY $D1$ RESTORES:

1. No action occurs when relay $D1$ restores, but it will restore slower than relay $G1$.

RELAY $F4$ RESTORES:

1. No action occurs when relay $F4$ restores, but it will restore slower than relay $B4$.

RELAY $G1$ RESTORES:

1. Contacts $1T$–$2T$ prepare the operating circuit for relay $B1$ through contacts 5–6 of relay $F1$.
2. Contacts $2T$–$3T$ further open a ground to the CN lead.
3. Contacts $4T$–$5T$ open the lock circuit to relay $H1$.

4. Contacts $6T$–$7T$ further open its (relay $G1$) lock circuit and the incomplete circuits to relays $C1$ and $A1$.
5. Contacts $1B$–$2B$ prepare a circuit to the call supply lamp and to relay $AR3$.
6. Contacts $2B$–$3B$ open a circuit to the call supply lamp and to relay $AR3$.
7. Contacts $4B$–$5B$ further open a talking circuit between the calling party and the repeater coil, $RC1$, in the local trunk.
8. Contacts $6B$–$7B$ open the circuit to the local line BUSY lamp (part 2) over the BY lead.

RELAY $AR3$ RESTORES:

1. Contacts 1–2 open the circuit to the night alarm buzzer (part 3A).

RELAY $H1$ RESTORES:

1. Contacts 2–3 and 5–6 further open the bridge circuit.
2. Contacts 8–9 open the first hold circuit to line relay $L2$ of line 37, and the operating circuit to relay $F1$.
3. Contacts 10–11 open the lock circuit to relay $F1$.
4. Contacts 12–13 open its (relay $H1$) incomplete lock circuit.

RELAY $F1$ RESTORES:

1. X contacts (1–2) open its (relay $F1$) incomplete lock circuit.
2. Contacts 3–4 prepare a bridge for the local trunk.
3. Contacts 5–6 prepare the circuit to relay $B1$.
4. Contacts 6–7 remove ground from the CN lead.
5. Contacts 8–9 remove ground from CN1 lead and remove its (relay $F1$) shunting ground.
6. Contacts 10–11 open an incomplete circuit to the local call supply lamp (part 2) over the LL lead, and to relay $AR3$ over the A lead.

RELAY *B*4 RESTORES:

1. Contacts 1–2 prepare the lock circuit to relay *D*4.
2. Contacts 2–3 open its incomplete lock circuit.
3. Contacts 4–5 open the talking circuit between the repeater coil, *RC*4, and the shore party and open a loop between the positive and negative line leads.
4. Contacts 6–7 open the circuit to the shore-line busy lamp (part 2) over the BY lead.

The circuit is now at normal.

Shore-to-Ship Calls

SEIZURE OF THE TRUNK.—When a line station ashore makes a call through the shore exchange, the ringing machine sends out ringing current from the connector in the shore exchange to operate relay *C*4 in the shore-line trunk over the positive and negative leads.

RELAY *C*4 OPERATES:

1. Contacts 1–2 complete the operating circuit to relay *D*4. (Relay *C*4 will operate and restore with ringing current pulses.)

RELAY *D*4 OPERATES:

1. Contacts 1–2 complete the circuit to the shore-trunk CALL lamp over the LL lead, and to relay *AR*3 over the A lead.
2. Contacts 3–4 complete its (relay *D*4) lock circuit.

RELAY *AR*3 OPERATES:

1. Contacts 1–2 complete the circuit to the night alarm buzzer (part 3A).

The circuit remains in this condition until the attendant answers the call.

ATTENDANT ANSWERS.—The attendant is signalled by the call lamp and buzzer. He answers the call by operating the shore TALK key (part 2) associated with this trunk and by removing the handset from the hookswitch.

SHORE TALK KEY (PART 2) OPERATED:

1. Contacts 1–2 complete the operating circuit to winding 1 of relay *B*4 over the CR lead.

2. Contacts 3–4 complete an operating circuit to relay *AT*1 (part 3) over the TG lead.
3. Contacts 5–6 and 7–8 prepare a talking circuit between the repeater coil, *RC*4, and the attendant. This circuit is from the T lead (part 4), through contacts 5–6 of the shore-line TALK key, over the T lead to the attendant's handset, out over the R lead, through contacts 7–8 of the shore TALK key, and back to the R lead (part 4).
4. Contacts 9–10 complete part of the circuit to winding 1 of relay *A*4 over the D1 lead.
5. Contacts 11–12 complete part of the circuit of relay *E*4 over the RR lead.

RELAY *AT*1 OPERATES:

1. Contacts 1–2 remove a multiple ground from the night alarm buzzer.

RELAY *B*4 OPERATES:

1. Contacts 1–2 open the lock circuit of relay *D*4.
2. Contacts 2–3 complete its (relay *B*4) first lock circuit.
3. Contacts 4–5 prepare a talking circuit between the repeater coil, *RC*4, and the shore line, and complete a bridge across the positive and negative shore leads to partially operate relay F_c in the connector (assuming a similar type of automatic shore exchange). This action shunts relay *C*4 with a relatively low resistance.
4. Contacts 6–7 complete the circuit to the shore trunk BUSY lamp over the BY lead.

RELAY *C*4 RESTORES:

1. Contacts 1–2 open the operating circuit to relay *D*4.

RELAY *D*4 RESTORES:

1. Contacts 1–2 open the circuit to the shore-line CALL lamp (part 2), over the LL lead and the circuit to relay *AR*3, over the A lead.
2. Contacts 3–4 open its incomplete lock circuit.

RELAY *AR*3 RESTORES:

1. Contacts 1–2 open the circuit to the night alarm buzzer.

HANDSET HOOKSWITCH (PART 3B) OPERATED:

1. Contacts 1–2 complete the attendant's receiver circuit.
2. Contacts 3–4 complete the circuit to relay *AT*3 over the L3 lead, and complete the transmitter circuit over the L3 lead, through winding 1–2 of the induction coil, to the L1 lead.

RELAY *AT*3 OPERATES:

1. Contacts 1–2 open an incomplete circuit to the night alarm buzzer (part 3A).

The attendant can now talk with the calling station to ascertain the desired number.

EXTENDING THE CALL TO A LOCAL TRUNK.—The attendant operates the calling trunk key associated with an idle trunk. The attendant also operates the talk key associated with this same idle trunk. Each call should be assigned to the same numbered shore and local trunk to provide a uniform method of handling calls. For example, if the call came in on shore-line trunk 1, the upper local trunk key is operated to the position designated TRUNK 1. Also, the attendant operates the local TALK key associated with the idle local trunk.

SHORE TRUNK KEY 1 (PART 2) OPERATED:

1. Contacts 1–2 complete an operating circuit to relay *D*1 from ground over the MR lead.
2. Contacts 3–4 and 5–6 complete the talking circuit between the repeater coils, *RC*1 and *RC*4. This circuit is from the shore line trunk over the T lead, through contacts 3–4 of the shore trunk key 1, over the T lead to the local trunk, to repeater coil, *RC*1, over the R lead, through contacts 5–6 of the shore trunk key 1, and back over the R lead, to the shore-line trunk, to the repeater coil, *RC*4.

3. Contacts 7–8 complete an operating circuit to relay $F4$ over the MR lead.

RELAY $D1$ OPERATES:

1. Contacts 2–3 prepare a lock circuit to relay $G1$ through contacts 3–4 of the local release key over the R1 and R2 leads.

RELAY $F4$ OPERATES:

1. Contacts 1–2 open the first lock circuit to relay $B4$.
2. Contacts 2–3 complete the second lock circuit to relay $B4$.

LOCAL TALK KEY (PART 2) OPERATED:

1. Contacts 1–2 complete an operating circuit to winding 1 of relay $G1$ over the CR lead.
2. Contacts 3–4 complete a hold circuit to relay $AT1$ (part 3) over the TG lead.
3. Contacts 5–6 and 7–8 complete a circuit between the repeater coil, $RC1$, and the attendant.
4. Contacts 9–10 prepare a circuit to relay $E1$.

RELAY $G1$ OPERATES:

1. Contacts $1T$–$2T$ further open a circuit to relay $B1$.
2. Contacts $2T$–$3T$ place ground on the CN lead.
3. Contacts $4T$–$5T$ prepare the lock circuit for relay $H1$.
4. Contacts $6T$–$7T$ complete its (relay $G1$) lock circuit, a polarizing circuit to winding 2 of relay $A1$, and prepare an operating and lock circuit to relay $C1$.
5. Contacts $1B$–$2B$ further open a circuit to a call supply lamp and to relay $AR3$.
6. Contacts $2B$–$3B$ prepare an operating circuit to a call supply lamp and relay $AR3$.
7. Contacts $4B$–$5B$ prepare a talking circuit from the repeater coil, $RC1$, to the called party, and complete a loop to the positive and negative leads.
8. Contacts $6B$–$7B$ complete a circuit to the local TRUNK BUSY lamp (part 2) over the BY lead.

RELAY $AT1$ (PART 3) OPERATES (ITEM 2 UNDER LOCAL TALK KEY OPERATED):

1. Contacts 1–2 open an incomplete circuit to the night alarm buzzer (part 3A).

Completion of the loop circuit by relay $G1$ operating will cause the local trunk line relay to operate partially. This action results in the attendant getting dial tone from a connector aboard ship.

The attendant can now release the shore TALK key associated with the shore trunk. However, it is not necessary to release this talk key unless the attendant desires to withdraw from the connection.

SHORE TALK KEY (PART 2) RELEASED:

1. Contacts 1–2 open the operating circuit of relay $B4$ over the CR lead.
2. Contacts 3–4 remove a multiple ground from relay $AT1$ (part 3) over the TG lead.
3. Contacts 5–6 and 7–8 open a talking circuit between the attendant and the repeater coil, $RC4$. This circuit is from the shore-line trunk over the T lead, through contacts 5–6 of the shore TALK key, over the T lead, to the attendant's handset, over the R lead, through contacts 7–8 of the shore TALK key, and back to the shore-line trunk, over the R lead.
4. Contacts 9–10 open an incomplete circuit to relay $A4$ over the D1 lead.
5. Contacts 11–12 open an incomplete circuit to relay $E4$ over the RR lead.

The completion of the loop across the local positive and negative leads to the ship's exchange extends these leads through to a connector. Dial tone indicates that dialing can commence. The attendant dials the number of the desired station in the ship. Each time the dial is rotated off normal, the circuit is completed to relay $AT2$ (part 3) over the D1 lead.

DIAL OPERATED:

1. Dial off-normal (D.O.N.) springs 2–3 complete an operating circuit to relay $AT2$.

RELAY $AT2$ (PART 3) OPERATES:

1. X contacts (1–2) short circuit the receiver of the attendant's handset to prevent loud clicks while he is dialing.
2. Contacts 4–5 short circuit the talking circuit between the repeater coils, $RC1$ and $RC4$.
3. Contacts 6–7 complete the operating circuit to relay $E1$.

RELAY $E1$ OPERATES:

1. Contacts 1–3 and 4–6 connect the positive and negative ship trunk line leads to the dialing circuit.
2. Contacts 2–3 and 5–6 remove the repeater coil, $RC1$, from the dialing loop.

DIAL RESTORES:

1. The dial impulses from contacts 4–5 of the dial impulse springs are sent out over the positive and negative ship line leads to cause the connector to signal the called party.
2. After the last digit has been dialed, contacts 2–3 of the D.O.N. springs open the circuit to relays $AT2$ and $E1$, which restore.

RELAY $AT2$ (PART 3) RESTORES:

1. X contacts (1–2) remove the short circuit from the receiver of the attendant's handset.
2. Contacts 4–5 open the short circuit on the talking circuit between the repeater coils, $RC1$ and $RC4$.
3. Contacts 6–7 further open the incomplete circuit to relay $E1$.

RELAY $E1$ RESTORES:

1. Contacts 1–3 and 4–6 open the dialing circuit.
2. Contacts 2–3 and 5–6 prepare a talking circuit from the repeater coil, RC1 to the called party.

When the number of the called line has been dialed, the local automatic switches test the called line. If the line is found busy, the switches return busy tone, and if the line is found free, the switches start automatic ringing

and return ring-back tone. When the called party answers, the talking circuits are completed between the attendant, the calling party, and the called party. The attendant now releases the talk key associated with the local trunk.

LOCAL TALK KEY (PART 2) RELEASED:

1. Contacts 1–2 open the operating circuit of relay *G*1 over the CR lead.
2. Contacts 3–4 open the hold circuit to relay *AT*1 (part 3) over the TG lead and relay *AT*1 restores.
3. Contacts 5–6 and 7–8 open the talking circuit between the attendant and the repeater coils, *RC*1 and *RC*4.
4. Contacts 9–10 open an incomplete circuit to relay *E*1 over the *D*1 lead.

RELAY *AT*1 (PART 3) RESTORES:

1. Contacts 1–2 prepare a circuit to the night alarm buzzer (part 3A).

RELAY *AT*3 RESTORES (WHEN THE HANDSET IS RESTORED):

1. Contacts 1–2 prepare a circuit to the night alarm buzzer (part 3A).

When the connector in the ship's exchange was seized by the local trunk, this connector placed ground on the local positive lead and negative battery on the local negative lead to complete the circuit to winding 1 of relay *A*1. Relay *A*1 did not operate at that time because its windings were energized in opposition to each other. However, when the called party answers, the connector reverses the battery polarity to the local positive and negative leads of the local trunk to energize winding 1 of relay *A*1 so that this winding now assists its (polarized) winding 2.

RELAY *A*1 OPERATES:

1. Contacts 1–2 further open a circuit to the local call supply lamp (part 2) and to relay *AR*3.
2. Contacts 3–4 complete the operating circuit to winding 1 of relay *C*1.

RELAY $C1$ OPERATES:

1. Contacts 1–2 prepare an operating circuit to the local call supply lamp (part 2) and to relay $AR3$.
2. Contacts 3–4 complete its own lock circuit.

The BUSY lamps associated with the local trunk and the shore trunk are both lighted and the talking circuit is complete between the calling party and the called party.

RELEASE.—The release of the connection is controlled by both the called party and the attendant (relays $D1$, $G1$, $A1$, $C1$, $B4$, and $F4$; and one shore trunk key operated).

When the called party replaces the receiver on the cradle switch, the circuit is opened to relay D_c in the connector. When relay D_c restores, it reverses battery to the local positive and negative leads to energize the windings of relay $A1$ in opposition to each other.

RELAY $A1$ RESTORES:

1. Contacts 1–2 complete a circuit to the local call supply lamp (part 2) and to relay $AR3$.
2. Contacts 3–4 open the operating circuit to relay $C1$.

RELAY $AR3$ OPERATES:

1. Contacts 1–2 complete a circuit to the night alarm buzzer (part 3A).

The call supply lamp and night alarm buzzer give the attendant release supervision. The attendant restores the shore trunk key associated with the proper call supply lamp. (In this example, shore trunk key 1).

SHORE TRUNK KEY 1 (PART 2) RELEASED:

1. Contacts 1–2 open the operating circuit of relay D1 and the lock circuits to relays $G1$ and $C1$.
2. Contacts 3–4 and 5–6 open the talking circuit between the repeater coils, $RC1$ and $RC4$.
3. Contacts 7–8 open the operating circuit of relay $F4$, and the lock circuit of relay $B4$.

RELAY $D1$ RESTORES:

1. No action occurs when relay $D1$ restores. However, it restores slower than relay $G1$ to prevent a false lock on relay $G1$.

RELAY $F4$ RESTORES:

1. No action occurs when relay $F4$ restores. However, it restores slower than relay $B4$ to prevent a false lock on relay $B4$.

RELAY $G1$ RESTORES:

1. Contacts $1T$–$2T$ prepare a circuit to relay $B1$, which is not used at this time.
2. Contacts $2T$–$3T$ open a ground circuit to the CN lead.
3. Contacts $6T$–$7T$ further open its lock circuit and open incomplete circuits to relays $C1$ and $A1$.
4. Contacts $1B$–$2B$ prepare a circuit to the call supply lamp and to relay $AR3$.
5. Contacts $6B$–$7B$ open the circuit to the local trunk BUSY lamp.

RELAY $AR3$ RESTORES:

1. Contacts 1–2 open the circuit to the night alarm buzzer (part 3A).

RELAY $C1$ RESTORES (ITEM 2 OF RELAY $A1$ RESTORES):

1. Contacts 1–2 open a circuit to the local call supply lamp and a circuit to relay $AR3$.
2. Contacts 3–4 further open its lock circuit.

RELAY $B4$ RESTORES:

1. Contacts 1–2 prepare a lock circuit to relay $D4$, which is not used at this time.
2. Contacts 2–3 further open its lock circuit.
3. Contacts 4–5 open the talking circuit between the repeater coil, $RC4$, and the shore party, and a loop circuit between the positive and negative leads.
4. Contacts 6–7 open the circuit to the shore-trunk BUSY lamp (part 2).

The circuit is now at normal.

Releasing Shore-Line Trunk Without Releasing Local Trunk

If the attendant desires to release the shore-line trunk without releasing the local trunk, the TALK key associated with the local trunk is operated. The shore release key

is then operated momentarily to open the loop to the positive and negative leads of the shore-line trunk. This action releases the equipment at the shore exchange and opens the lock circuit to winding 2 of relay *B*4. If the shore-line TALK key associated with the shore-line trunk is not operated at this time, relay *B*4 will restore. However, if this TALK key is operated, winding 1 of relay *B*4 will hold this relay operated.

RELAY *B*4 RESTORES:

1. Contacts 4–5 further open the incomplete loop to the shore-line trunk.
2. Contacts 6–7 open the circuit to the shore trunk BUSY lamp.

When the shore release key (part 2) is restored, the loop is completed to the shore-line trunk through contacts 4–5 of relay B4 if this relay is still operated. On the other hand, if relay B4 is not operated, the release of the shore release key only prepares the loop, and the attendant must operate the shore TALK key associated with the shore-line trunk in order to seize the loop.

Releasing Local Trunk Without Releasing Shore-Line Trunk

If the attendant desires to release the local trunk without releasing the shore-line trunk, the TALK key associated with the shore-line trunk is operated. The local release key is then operated momentarily to open the loop to the positive and negative leads of the local trunk. This action releases the equipment at the local ship's exchange and opens the lock circuit to winding 2 of relay *G*1. If the local TALK key associated with the local trunk is operated when the local release key is operated, winding 1 of relay *G*1 will hold this relay operated. However, if this TALK key is not operated, relay *G*1 will restore.

RELAY *G*1 RESTORES:

1. Contacts 6*T*–7*T* open part of its (relay *G*1) lock circuit.
2. Contacts 4*B*–5*B* further open the loop circuit to the local trunk.

3. Contacts $6B$–$7B$ open the circuit to the associated local BUSY lamp.

When the local release key is restored, the loop circuit is completed if relay $G1$ is operated; or the loop circuit is prepared, if relay $G1$ has been released to the local trunk.

If the relay $G1$ is not operated, the associated TALK key must be operated to reseize the local trunk. The trunk is seized when the loop is completed.

Unanswered Calls

FROM A SHORE EXCHANGE.—When a call from a shore exchange is not answered, the calling party can release.

Relay $D4$ remains operated through its locking contacts 3–4. It was initially operated by contacts 1–2 of relay $C4$, which was operated in turn by the shore-exchange ringing current because $C4$ is an a-c relay.

Relay $AR3$ remains operated through contacts 1–2 of relay $D4$. The shore-line call lamp and the night alarm buzzer remain operated.

When the attendant operates the TALK key and finds that the calling party has disconnected, the attendant momentarily operates the shore release key to restore the circuit to normal.

FROM THE SHIP'S EXCHANGE.—When a call from the ship's exchange is released unanswered, the circuit is returned to normal.

Out-of-Order Key

An out-of-order condition of the local or shore-line trunks is indicated by the downward position of the out-of-order key handle (opposite the TALK key) associated with the trunk that is out of order.

Night Alarm Buzzer

The night alarm buzzer operates when a call lamp is lighted. Relays $E1$ and $A4$ are each provided with a 500-ohm noninductive winding connected across the filaments of the associated call lamps. This condition ensures op-

eration of the night alarm buzzer in case the associated call lamp filament should burn out.

Fuse Lamp

When a fuse in the attendant's cabinet blows, the fuse lamp on the lamp and key panel is lighted to signal the attendant.

QUIZ

1. What are the four basic units that make up the dial telephone power equipment?
2. What is the voltage rating of the storage battery?
3. What is the primary purpose of the motor-generator?
4. Why cannot a reversal of current in the series turns of the generator cause a reversal of flux in the main field?
5. Why cannot this generator run away when it accidently motors?
6. What are the 10 basic types of equipment that comprise the power panel?
7. What does the voltmeter indicate when the voltmeter switch is in the NORMAL position?
8. What is the condition of the generator circuits when the GENERATOR switch is in the NORMAL position?
9. What is the function of the GENERATOR OUTPUT switch?
10. What three supervisory alarms are provided for the power equipment?

    Refer to figure 13–2 for questions 11 through 22:
11. When starting the motor-generator, what completes the operating circuit to the solenoid of the across-the-line starter?
12. Before cutting in the generator, what prepares the circuits to relays *PC*6 and *PC*5?
13. What voltage must the generator build up to before it can be cut in?
14. When cutting in the generator: (a) What operates relay *PC*5? (b) What completes the circuit to the shunt coil of relay *PC*6? (c) What short circuits the contacts of the generator output switch? (d) What opens a multiple circuit to relay *PC*5? (e) On what voltage does relay *PC*6 operate? (f) What opens the circuit across resistor *PR*? (g) What completes the operating circuit to relay *PC*4? (h) What opens the circuit to relay *PC*5? (i) What opens a multiple circuit to the shunt coil of relay *PC*6?

15. When stopping the motor-generator: (a) What opens the operating circuit to relay *PC*4? (b) Why is an alarm not sounded under normal conditions of releasing?

16. If the motor-generator should fail: (a) What restores relay *PC*6? (b) What opens the operating circuit to relay *PC*4? (c) What completes ground (+ GEN) on the CFR lead? (d) What opens the hold circuit to the shunt coil of relay *PC*6?

17. To restart the motor after an overload has released the motor starter, what three operations must be performed and in what sequence?

18. If the exchange battery falls below a predetermined value or if the power supply fuse is blown: (a) What completes the circuit to the buzzer over the A and AG leads? (b) What completes the circuit to the power fail lamp over the A and AB leads? (c) When the voltage returns to normal, what cuts off the power fail alarm?

19. If the generator fails after cut in, what causes an audible and visual alarm signal in the ring and tone machine, timer, and alarm circuits after a predetermined delay?

20. When the alarm fuse blows, what opens the CFR lead?

21. When the power supply fuse blows, what completes the circuit to the buzzer on the A and AG leads?

22. When the power supply fuse is replaced, what stops the power fuse alarm?

23. What is the attendant's cabinet used for?

24. What does the top compartment of the attendant's cabinet contain?

25. What does the bottom compartment of the attendant's cabinet contain?

26. What does the center compartment of the attendant's cabinet contain?

27. In what does each of the four two-way shore trunks and the four two-way local trunks terminate?

28. What does the lamp and key strip for each local trunk contain?

29. The shore trunk keys (upper and lower) provide what connection facility between any local trunk and any shore-line trunk?

30. What is the function of the push-switch type release key provided for each trunk?

31. What three conditions are provided by the call lamp, the busy lamp, and the buzzer?

32. What is the purpose of the shore-line control switch?

33. What is the function of the shore-line fuse and protector equipment?

34. What is the purpose of the line transfer relays?

35. On a ship-to-shore call, what completes the operating circuit to the line relay, *L*2, of line 37?

Refer to figure 13–6 for questions 36 through 59:

36. On a ship-to-shore call, what completes the first hold circuit on line relay *L*2 of line 37?

37. On a ship-to-shore call, what prepares the talking circuit between the repeater coil *RC*1 and the attendant when the local talk key is operated?

38. On a ship-to-shore call, what completes the lock circuit to relay *H*1?

39. On a ship-to-shore call, what completes the talking circuit between the calling party and the repeater coil, *RC*1?

40. Why will relay *A*1 not operate when only its winding 2 is energized?

41. On a ship-to-shore call, what completes the talking circuit between the calling party and the attendant?

42. On a ship-to-shore call, what extends the talking circuit from the local trunk to the repeater coil, *RC*4, in the shore-line trunk?

43. On a ship-to-shore call, what extends the talking circuit from the repeater coil, *RC*4, in the shore-line trunk to the attendant?

44. On a ship-to-shore call, what prepares a talking circuit from the repeater coil, *RC*4, in the shore-line trunk to the called party?

45. On a ship-to-shore call, what opens the operating circuit over the CR lead to winding 1 of relay G1?

46. On a ship-to-shore call, what completes the operating circuit over the D1 lead to relay *AT*2 in the attendant's cabinet?

47. On a ship-to-shore call, what short circuits the receiver of the attendant's handset to prevent loud clicks while he is dialing?

48. On a ship-to-shore call, what prepares the talking circuit from the repeater coil, *RC*4, to shore?

49. On a ship-to-shore call, what opens the attendant's talking circuit when the called party answers.

50. On a ship-to-shore call, what removes the shunt from relay F1 when the calling party releases?

51. On a ship-to-shore call, what opens the talking circuit between the repeater coils, $RC1$ and $RC4$, when the calling party releases?

52. On a ship-to-shore call, what further opens a talking circuit between the calling party and the repeater coil, $RC1$, when the calling party releases?

53. On a ship-to-shore call, what opens the first hold circuit to a line relay $L2$ of line 37 and the operating circuit to relay $F1$ when the calling party releases?

54. On a ship-to-shore call, what opens the lock circuit to relay $F1$ when the calling party releases?

55. On a ship-to-shore call, what opens the talking circuit between the repeater coil, $RC4$, and the shore party, and the loop between the positive and negative line leads when the calling party releases?

56. On a shore-to-ship call when ringing the attendant's cabinet: (a) What causes relay $C4$ to energize and release periodically? (b) What completes the operating circuit to relay $D4$? (c) What completes the circuit to the shore trunk CALL lamp and to relay $AR3$? (d) What completes the circuit to the night alarm buzzer?

57. On a shore-to-ship call when the attendant answers, (shore talk key operated): (a) What completes an operating circuit over the TG lead to relay $AT1$? (b) What prepares a talking circuit between the repeater coil, $RC4$, and the attendant? (c) What removes a multiple ground from the NIGHT ALARM buzzer? (d) What completes a bridge across the POSITIVE and NEGATIVE shore leads to partially operate relay F_c in the (shore exchange) connector? (e) What completes the circuit to the shore trunk BUSY lamp over the BY lead? (f) What opens the circuit to the night alarm buzzer? (g) What completes the transmitter circuit to the attendant's handset over the L3 lead through winding 1–2 of the induction coil to the L1 lead?

58. When extending a shore-to-ship call to a two-way local trunk: (a) What completes the talking circuit between the repeater coils, $RC1$ and $RC4$? (b) What completes a circuit between the repeater coil, $RC1$, and the attendant? (c) What places ground on the CN lead? (d) What prepares a talking circuit from the

repeater coil *RC*1, to the called party, and completes a loop to the positive and negative leads? (e) What causes dial tone in the attendant's set from a connector aboard ship? (f) What causes the connector to signal the called party? (g) After dialing is completed, what opens the shore circuit on the talking circuit between the repeater coils, RC1 and RC4? (h) What opens the talking circuit between the attendant and the repeater coils, *RC*1 and *RC*4? (i) When the called party answers, what operates relay A1? (j) What controls the release of the shore-to-ship connection?

59. (a) When the called party replaces the receiver on the hookswitch, what completes a circuit to the local call supply lamp? (b) What opens the talking circuit between the repeater coils, *RC*1 and *RC*4? (c) What opens the talking circuit between the repeater coil, *RC*4, and the shore party, and opens a loop circuit between the positive and negative leads?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

ORGANIZATION AND ADMINISTRATION

1. (1) Mechanical elements that comprise the organization structure, and (2) dynamic elements that concern the integration of the human factors into this structure.
2. The organization structures for (1) battle, (2) administration, and (3) watches.
3. Organization charts.
4. The Watch, Quarter, and Station Bill.
5. Job descriptions.
6. The *Ship's Organization and Regulations Manual.*
7. To provide the ships personnel with a ready source of authoritative information concerning their duties, responsibilities, and authorities in administering and operating the ship.
8. Detailed information concerning duties, responsibilities, and authority of personnel within the department or division.
9. (1) To delegate the authority of department heads, or division officers, and (2) to assign duties and responsibilities to subordinates.
10. In a large department the Department Organization Manual may only prescribe the delegation of authority by the head of the department to his key subordinate officers, and the Division Organization Manual may be necessary to delegate authority through the petty officer levels. On the other hand, in small departments, the Department Organization Manual may also serve as the Division Organization Manual.
11. By a notation of the station assigned or the duty to be performed opposite the man's name in the columns headed by the applicable Ship's Organization Bills.
12. The ship's Battle Organization Manual.

13. (1) Man the stations for battle, (2) perform the basic administrative requirements, and (3) maintain the continuous watches required under wartime conditions.

14. The allowance is based on the percentage of the complement necessary to maintain and operate the ship under peacetime conditions.

15. (1) National policy and (2) budgeting limitations.

16. (a) Three. (b) Each section must be adequate to maneuver and fight the ship under emergency conditions.

17. (1) Number and (2) qualifications of available personnel.

18. They are responsible for the operation, maintenance, and repair of the specific equipment included in their group.

19. To keep them advancing by broadening their knowledge, and also in order to always have several men with a good working knowledge of each equipment.

20. "Paper work" is assigned that is commensurate with the individual's rating and, when practicable, personnel can also be rotated among the various types of paper work.

21. (a) Maintenance and (b) records and replacement parts.

22. He is responsible, under the Engineer Officer, for the organization, administration, and operation of his division and its assigned personnel and material.

23. He is responsible, under the Electrical Officer, for the readiness of all assigned electrical equipment and the administration of the electrical maintenance program.

24. To organize the activities of the group members toward the accomplishment of a given task.

25. No.

26. Through the voluntary cooperation of the men with their leader.

27. The art of getting along with people.

28. (1) Dependability, (2) punctuality, (3) consideration, and (4) tact.

29. Because the operational readiness of every unit in the Navy depends, to a great extent, on the knowledge and skill of every crew member.

30. (1) Technical ability, (2) personality, (3) enthusiasm, (4) sense of humor, (5) sense of responsibility, (6) ingenuity, and (7) military bearing.

31. (1) Lectures, (2) discussions, (3) demonstrations, (4) pupil coaching, (5) laboratory work, and (6) actual maintenance.
32. By developing dexterity, precision, and the knack of handling tools, which are obtained only through work experience.
33. (1) Instructor explains importance of job. (2) Instructor does the job and explains each step. (3) Instructor does the job; trainee explains each step. (4) Trainee does the job and explains each step. (5) Instructor corrects the errors.
34. (1) Knowing the subject matter thoroughly and (2) being well prepared to give instructions.
35. From 1 to 2 hours.
36. A program that requires each technician to give a series of lessons on the equipment that he maintains.
37. To maintain an individual training record in duplicate for each man.
38. (1) Lesson plans and (2) progress charts.

CHAPTER 2

GAS-FILLED ELECTRON TUBES

1. (a) Lower. (b) Because of a low pressure inert gas in the tube envelope.
2. Low.
3. High.
4. Ability to handle sudden high current demand.
5. (1) Amount of current and (2) magnitude of the voltage applied between the plate and cathode.
6. (a) (1) Space charge, (2) spacing between the plate and cathode, and (3) size of the plate and cathode.
   (b) By introducing a small amount of inert gas into the envelope after the air has been evacuated.
7. Because the voltage drop represents a loss that never reaches the load.
8. (1) Argon, (2) neon, (3) nitrogen, (4) xenon, and (5) mercury vapor.
9. (a) The collision of electrons with atoms causes the atoms to release an electron and thereby to become ions. (b) Positive.
10. (a) Positive ions neutralize the space charge, which (b) results in increased emission current and less opposition to current flow.

11. (1) Reduces the required voltage between the plate and cathode, and (2) maintains the voltage drop through the tube practically constant with load change.
12. (1) Ionization, (2) striking potential, (3) critical potential, (4) firing point, or (5) breakdown point.
13. Lower.
14. The gas deionizes and conduction stops.
15. (1) Deionizing potential and (2) extinction potential.
16. Almost infinite resistance before and almost zero resistance after ionization.
17. The tube may permit current to flow in the reverse direction (arcback).
18. Inversely with the temperature and pressure of the gas.
19. The cathode may be destroyed by positive-ion bombardment.
20. The tube may arcback because too many ions remain between the plate and cathode on the negative half cycle.
21. Because no appreciable space-charge effect exists to limit the current flow that might destroy the tube.
22. The same symbol as for a vacuum diode, except that a black dot is added inside the circle.
23. Because with excessive voltage drop across the tube and more charge on the positive ions, they will travel at excessively high speed toward the cathode.
24. The cathode is not heated and no electrons are emitted to help the ionization process.
25. The glow surrounds the negative electrode or cathode.
26. (1) Voltage regulator, (2) light source, (3) part of a relaxation oscillator, (4) rectifier, and (5) as a control for the circuit continuity in noise limiters.
27. The thyratron is a gas-filled triode or tetrode; whereas, the high-vacuum type is not.
28. Because the output waveform is not a reproduction of the input waveform.
29. (a) The grid loses control. (b) A sheath of positive ions is formed around the grid, thereby neutralizing the negative charge on the grid.
30. The a-c plate voltage periodically reverses and the tube deionizes at which time the grid loses its sheath of positive ions.

31. 400 volts.

32. Greater.

33. (1) Amplitude, (2) phase shift, and (3) saw tooth.

34. Because beyond this range the plate voltage decreases and cannot fire the tube.

35. Increases.

36. In series.

37. By varying the amplitude and slope of a saw-tooth voltage that acts in series opposition with respect to a steady d-c bias.

38. Late firing is accomplished by increasing the amplitude of the saw-tooth voltage; early firing is accomplished by decreasing the amplitude of the saw-tooth voltage.

39. By varying the d-c voltage in the grid circuit.

40. By varying the component of a-c grid voltage that is supplied from the same phase that supplies the a-c plate voltage.

41. $V1$, $T1$, $R1$ and $C1$.

42. To provide a higher degree of accuracy.

43. Zero.

CHAPTER 3

BASIC MECHANISMS

1. (1) Direction in degrees, (2) distance in yards, and (3) speed in knots.

2. Shaft rotation in one direction increases the value; whereas, rotation in the opposite direction decreases the value.

3. 36°.

4. 4.

5. 22.5°.

6. Pinion.

7. Rotary motion.

8. Linear.

9. Spur gears.

10. In a straight spur gear, the teeth are cut parallel to the axis of rotation; whereas, in a helical spur gear the teeth are cut with a lead angle (some angle other than parallel to the axis of rotation).

11. In the helical gears, the meshing action is much smoother, resulting in quieter operation than in spur gears because more than one tooth is in mesh at a time.

12. Bevel gears.

13. In a straight bevel gear the teeth are cut straight across the face of the gear; whereas, in a spiral bevel gear the teeth are cut with a lead angle across the face of the gear blank.

14. Two bevel gears of the same size, the shafts of which are at right angles.

15. On the inside circumference of a ring and parallel to the axis of rotation.

16. The axis of the external gear is parallel to, but offset from, the axis of the internal gear.

17. A helical screw.

18. 1:16

19. (a) 1:8. (b) 1:16.

20. Large.

21. 2:7

22. Opposite directions.

23. Between the driver and driven gears to turn the driven gear in the same direction as the driving gear.

24. It does not affect the gear ratio.

25. Gear ratio $= \dfrac{\text{number of threads on worm}}{\text{number of teeth on worm wheel}}$.

26. Speed ratio.

27. Inverse to each other.

28. 4:1.

29. The driving gear would be too large and cumbersome and would waste valuable space.

30. A gear mechanism that adds or subtracts the inputs of two shafts and translates the total, or difference, through a third shaft.

31. (1) Bevel-gear differential, (2) jewel-gear differential, and (3) internal-gear differential.

32. Because the spider only makes half as many revolutions as the sum of, or difference, between the revolutions of the end gears.

33. Spur gears.
34. (a) Small, (b) light, and (c) exact.
35. (1) Single-phase capacitor motor and (2) single-phase shaded-pole motor.
36. The servomotor must (a) start and stop quickly and (b) be electrically reversible.
37. The heart cam and the indented cam.
38. Ball bearing mounted so that it is free to turn.
39. It keeps the follower roller firmly seated in the valley of the heart cam.
40. The heart cam is rotated so that either CW or CCW comes into contact with C.
41. Opposite.
42. The signal that is used to control the output power is equal to the difference between the input signal and the feedback signal.
43. To measure the difference, or error, in position between the output and the input.
44. The spider remains stationary and holds the contacts closed, thereby allowing the servomotor to operate continuously in a direction to open the contacts.
45. (1) Bearing-mounted synchro receiver, (2) synchro transmitter, and (3) contact assembly.
46. Directly.
47. Indirectly by means of a ratchet.
48. To convert a variable rate of rotation to a proportional angular displacement that can be transmitted to indicators.

CHAPTER 4

SHIP'S METERING AND INDICATING SYSTEMS

1. (1) Indicates the rpm, (2) direction of rotation, and (3) total revolutions of the individual propeller shafts.
2. To transmit the rotary motions of the propeller shafts to the master transmitter-indicators.
3. To convert the received rotary motion of the shaft transmitters into stationary angular synchro displacements, which are transmitted to the indicators.

4. To repeat the rpm readings received from the associated transmitted-indicators.
5. To cause the type-5G transmitter and counter assembly to always turn in one direction regardless of shaft rotation direction.
6. (1) Running synchro receiver, (2) speed-measuring mechanism, and (3) type-5G positioning synchro transmitter.
7. To receive the angular displacement from the speed-measuring mechanism and to transmit this displacement to the remotely located indicators.
8. (1) Transmitter of the magneto type geared to the propeller shaft and (2) indicators of the voltmeter type connected directly to the magneto.
9. The magneto converts the speed of the propeller shaft into a proportional d-c voltage, and the indicators receive this voltage and indicate, by an angular deflection on the associated scales, the rpm of the propeller shaft.
10. (1) Magneto, (2) type-1G synchro transmitter, (3) revolution counter, and (4) unidirectional mechanism.
11. By a SPDT switch and a DPDT relay that transposes the magneto connections to the terminal strip.
12. (1) Meter, (2) type-1F synchro repeater, (3) revolution counter, and (4) backing signal.
13. By means of a d-c voltmeter calibrated in terms of shaft rpm.
14. (1) To indicate the wind direction in degrees relative to the ship's heading, and (2) to indicate the wind intensity in knots relative to the ship.
15. (a) A type-1F direction synchro and a type-1F intensity synchro. (b) The direction synchro is mounted in the vertical support assembly of the vane, and the intensity synchro is mounted in the head of the vane.
16. To receive the angular directional displacements and the rotary motions from the respective foremast transmitters and to retransmit these indications and displacements to wind direction and intensity indicators.
17. An increase of the electrolytic impurities (principally salt) in water increases the electrical conductivity of the water and, conversely, a decrease in the impurities increases the electrical resistance of the water.
18. Power factor.

19. (a) The automatic temperature compensating resistor in series with one movable coil and the salinity cell in series with the other movable coil. (b) The ratio of the cell resistance to the compensator resistance. (c) To compensate for changes in cell resistance due to temperature changes so that only a change in the current ratio caused by a change in salinity can vary the meter reading. (d) In series opposition. (e) It decreases the thyratron control grid voltage, and the tube conducts.

20. To measure and indicate the speed of the ship and the distance traveled through the water.

21. (1) The hydraulic and (2) propeller types.

22. (1) Rodmeter, (2) sea value, (3) rotary distance transmitter, and (4) control unit.

23. As close to the keel as possible and at the turning point of the ship.

24. The dynamic orifice is located on the leading edge of the rodmeter tip, and there are two static orifices, one in each side of the rodmeter tip.

25. Equal static pressure on the static and dynamic orifices.

26. The differential pressure is equal to the difference between the pressures at the dynamic orifice and static orifices.

27. (a) Rotary distance transmitter and (b) control unit.

28. (1) Motor-driven centrifugal pump, (2) distance transmitting unit, and (3) transtat assembly.

29. (a) The master speed indicator and (b) the DRA.

30. To connect the rotary motion from the 60-rpm transmitter in the rotary distance transmitter to an instantaneous indication of the ship's speed in knots and to transmit this indication to the various speed and distance indicators.

31. To repeat the speed readings of the master speed indicator and to register the distance traveled.

32. (1) Propeller type of rodmeter, (2) rodmeter amplifier, and (3) transmitter-indicator.

33. To amplify the output of the 2-phase rodmeter generator sufficiently to drive the 2-phase synchronous motor in the transmitter-indicator.

34. To combine in one location the controls, indicators, and communications instruments formerly scattered about the bridge.

35. To provide a convenient grouping in one location of a large number of sound-powered telephone circuits, radio circuits, and ship's intercommunications stations.

CHAPTER 5

PRINCIPLES OF MAGNETIC AMPLIFIERS

1. (1) High efficiency, (2) reliability, (3) ruggedness, (4) space and weight economy, and (5) no warm-up time.
2. (1) It cannot handle low-level signals, (2) is not useful at high frequencies, (3) has a time delay in signal response, and (4) output waveform is not an exact reproduction of the input waveform.
3. (1) Saturable reactors, (2) dry-disk rectifiers, (3) fixed resistors, (4) variable resistors, and (5) conventional transformers.
4. (1) High-permeability alloys and (2) grain-oriented alloys.
5. High values of saturation flux density and relatively narrow loops with steep sides.
6. (1) Permalloy A, (2) Mumetal, and (3) 1040 alloy.
7. (1) Orthonol, (2) Deltamax, and (3) Permenorm 5000-Z alloy.
8. (a) Rectangular. (b) Almost infinite. (c) Almost complete.
9. (a) The thyratron grid and the thyratron cathode-plate circuit.
   (b) To limit the load current.
   (c) To control the action of the load winding.
10. By introducing a high impedance for a controlled portion of each half cycle and then removing this impedance to allow load current to flow during the remaining portion of the half cycle.
11. The magnetization is reset or changed to another operating point on the hysteresis loop.
12. The same.
13. To prohibit current flow in the load (gating) circuit during the reset half cycle and to prohibit current flow in the control circuit during the gating half cycle.
14. (a) Into the polarity marked terminal and (b) positive.
15. Opposite.
16. The rectifier prevents the flow of load current.
17. The inverse voltage on the rectifier is equal to the difference between the applied voltage and the mutually induced voltage in the load winding.

18. Opposite.

19. (1) The magnitude of the applied voltage across the control winding and (2) the time interval during which this voltage is applied.

20. From positive saturation, ϕ_1, to negative saturation, ϕ_2.

21. (a) The control winding. (b) Reset.

22. The flux change from ϕ_1 to ϕ_2 cuts the control winding, thereby inducing a voltage in the winding that opposes e_{ac} and limits the current to a small value.

23. The rectifier blocks the flow of current.

24. The rectifier permits the flow of current.

25. The mmf of the load winding opposes the residual flux ϕ_2, and is in a direction to change the flux to the ϕ_1 level.

26. Maximum impedance.

27. (a) No effect. (b) Because e_c is opposed to e_{ac} and at no time does e_{ac} exceed e_c.

28. The direction e_c is against the rectifier, therefore the rectifier prevents the flow of battery current.

29. (a) Zero. (b) Because e_c is against the rectifier, hence the rectifier is essentially an open circuit.

30. The rectifier in the control circuit blocks it.

31. (a) The polarity of e_{ac} is such as to tend to drive the core further into positive saturation. (b) None. (c) None. (d) R_L. (e) The full value, $\frac{e_{ac}}{R_L}$.

32. (a) Because during this interval e_{ac} is less than e_c, and the rectifier opposes e_c. (b) Because during this interval e_{ac} is greater than e_c and is not opposed by the rectifier. (c) The core flux changes from ϕ_1 to ϕ_3 (fig. 5–2, B). (d) The flux changes from ϕ_3 to ϕ_1. (e) High. (f) Magnetizing current. (g) It becomes saturated. (h) They are proportional. (i) They are proportional. (j) The magnitude of $e_{ac} - e_c$ applied to the control winding determines how far the flux is carried from positive saturation toward negative saturation, and consequently how much of the gating second half cycle will be nonconducting. (k) Directly.

33. (a) The control winding of core ① and the load winding of core ②. (b) Positive saturation, level 1, to negative saturation level 2 (fig. 5–3, F). (c) Negative saturation, level 2, to posi-

tive saturation, level 1 (fig. 5–3, F). (d) Maximum. (e) Zero. (f) They block the flow of current.

34. (a) The control winding of core ② and the load winding of core ①. (b) From positive saturation, level 1 (fig. 5–3, F) to negative saturation, level 2. (c) From negative saturation, level 2 (fig. 5–3, F) to positive saturation at level 1. (d) Maximum. (e) Zero. (f) They block the flow of current.

35. (a) 1 and 2. (b) Because e_c is equal and opposite to e_{ac} peak, and the rectifier blocks the flow of battery current when e_c is greater than e_{ac}. (c) It causes magnetizing current to flow, which changes the level of flux from level 2 to level 1.

36. (a) Core ② is already saturated in a positive direction and no flux change occurs; the load winding develops no impedance to the flow of load current and e_{ac} appears across R_L. (b) The full value, $\frac{e_{ac}}{R_L}$.

37. (a) None. (b) Because e_c is equal and opposite to e_{ac}; the rectifier will block the flow of battery current during the time that e_c is greater than e_{ac}; thus, the rectifier acts as an open circuit. (c) None. (d) Because the core is already at positive saturation, and the load current is in a direction to drive the core further into positive saturation. (e) The full value, $\frac{e_{ac}}{R_L}$.

38. (a) Negative. (b) No. (c) Because the windings are connected so that when e_{ac} is positive for core ① it is negative for core ②. (The rectifiers block the flow of current when e_{ac} is positive; they permit the flow of current when e_{ac} is negative.)

39. 1 and 2.

40. (a) Zero. (b) Because e_c is greater than e_{ac} and is opposed by the rectifier in the control winding circuit of core ①.

41. (a) A small magnitude of magnetizing current. (b) Because e_{ac} is greater than e_c, and the rectifier will not block the flow. The flux change causes an induced emf, which limits the current to a small value. (c) The extent of the flux change depends on $e_{ac} - e_c$ on the control winding. (d) 1 to 3.

42. (a) 3 to 1. (b) Core (1) saturates. (c) It decreases to zero.

43. (a) Zero. (b) Because the rectifier in the load winding of core (1) is against e_{ac}.

44. (a) A small value of magnetizing current. (b) Because the flux in core ② changes through its full range.

45. (a) Zero. (b) Because e_c is greater than e_{ac}, and the rectifiers block the flow of battery current.

46. (a) A small value of magnetizing current. (b) Because e_{ac} exceeds e_c and is not blocked by the rectifiers. (The flux change causes an induced voltage, which limits the flow of current to a small value.) (c) 1 to 3.

47. (a) A small value of magnetizing current. (b) 3 to 1. (c) High. (d) It decreases to zero. (e) Core ② becomes saturated (level 1) (fig. 5–3, F).

48. (a) The distance that the cores are reset from level 1 along the hysteresis loops toward level 2. (b) It depends directly on the magnitude of e_c. (c) It is relatively large.

49. (a) It reduces the power output. (b) It causes a further reduction in power output. (c) It reduces the power output.

50. The response time of the magnetic amplifier is increased.

CHAPTER 6

MAGNETIC AMPLIFIER APPLICATIONS

1. (a) As regulators to control the voltage, current, and frequency of the main propulsion plant and of auxiliary units. (b) Voltage and speed regulators for the 400-cycle power supply that is used with I. C. and F. C. equipment.

2. Below saturation the generated voltage is always proportional to the d-c field current.

3. To provide proper amount of fed current to maintain terminal voltage constant for any specified load and power-factor changes.

4. Rectifiers fed from the a-c generator output.

5. (a) It lowers X_m. (b) It lowers I_{fi}. (c) It lowers E_t.

6. (a) (1) Input circuit, (2) reference circuit, (3) comparison circuit, (4) magnetic amplifier $1SX$ and $2SX$ circuits, (5) reactive compensation circuit, and (6) stabilizing circuit. (b) (1) Input and (2) saturable reactor current transformer. (c) The load winding of the first stage, $1SX$, supplies the control winding of the second stage, $2SX$, and the load winding of the second stage supplies the control winding of the $3SX$ stage. The output of the $3SX$ stage supplies the saturating winding of the saturable current transformer and thus controls the magnitude of the generator field current. (d) 1000.

7. (a) A single phase transformer, $T2$ and two T-connected transformers, $T3$. (b) A 3-phase voltage proportional to the generator bus voltage and a single-phase reference voltage. (c) Two single-phase voltages to supply amplifier stages, $1SX$ and $2SX$.
8. To supply a nearly constant current to the comparison circuit.
9. The current that is effective in controlling the $1SX$ stage is equal to the difference in the reference current and the signal current.
10. It is used to alter the signal current, I_2, and thereby regulates the terminal voltage value of the a-c generator.
11. It increases I_2 proportionally.
12. It swings the control current in a positive direction.
13. It increases the average load current.
14. It (a) reduces the generated voltage and (b) checks the rise in terminal voltage.
15. To provide individual voltage drop compensations to secure proper division of the reactive load between generators operating in parallel.
16. To prevent voltage regulator hunting when making excessive field-voltage corrections.
17. (1) Manual control of the voltage when the regulator is not in use, (2) a third stage of amplification when the regulator is in use, and (3) a field flashing circuit including a separate 40-kw, d-c generator.
18. To rectify the output of 3-phase transformer T1 and to provide control of the third stage $3SX$ and the excitation system.
19. One.
20. To furnish sufficient field current to start the system initially.
21. A magnetic particle clutch.
22. (a) The inner-driving assembly is connected to the motor shaft, and the outer-driven assembly is connected to the generator shaft. (b) A mixture of iron particles and graphite. (c) The higher the coil current, and the stronger the magnetic field, and less the clutch slippage.
23. To automatically adjust the clutch-coil current to control the output frequency of the a-c generator.
24. (1) Motor controller, (2) master switch, (3) automatic-manual transfer switch, (4) speed regulator, and (5) voltage regulator.

25. (1) Magnetically operated contactor, (2) overload relays, and (3) pilot circuit fuse.

26. To permit operation of the controller independently of the overload protection.

27. (1) Starting circuit, (2) resonant detector circuit, (3) preamplifier circuit, and (4) power amplifier circuit.

28. Because there is no immediate excitation on the control coil of the magnetic particle clutch.

29. Relay S operates to close contact S1 and to open contacts $S2$, $S3$, and $S4$. This action disconnects the 60-cycle supply and connects the 400-cycle supply.

30. (a) To maintain the output frequency of the motor generator at approximately 400 cycles. (b) By establishing low and high frequency limits on any variations of the 400-cycle output.

31. (a) Little voltage is available. (b) More voltage is available.

32. The current in the control coil increases, thereby reducing the slip of the clutch and increasing the frequency.

33. To interconnect the load division assemblies and to remove the short circuit across these assemblies when two 400-cycle power supplies are operated in parallel.

34. To maintain equal load on each 400-cycle power supply system for parallel operation of two systems.

35. To provide a more sensitive clutch response to changes in both the load balance between the generators and input frequency.

36. (a) Two. (b) Resistor $R9$ and resistors $R1$ and $R2$. (c) It increases the voltage. (d) It increases the voltage. (e) The same. (f) To change the voltage. (g) Higher.

37. (a) (1) Voltage detector, (2) preamplifier, and (3) power amplifier. (b) To sense voltage changes in the generator output voltage to supply a signal to the preamplifier that is proportional to these changes. (c) To amplify voltage changes and supply them to the power amplifier. (d) To control the excitation current to the generator field.

38. (a) The 3-phase, 440-volt, 60-cycle ship service generator. (b) Its own armature. (c) The 3-phase, 440-volt, 60-cycle bus. (d) To regulate the current in the control windings, $1C$–$2C$, of $1SX$. (e) The field current increases.

39. (a) The third harmonic. (b) They cancel. (c) Because the secondaries of $T7$ are in closed delta.

40. To set the level at which the generator output voltage is regulated.

41. To the control winding, $1C$–$2C$, of the preamplifier $3SX$.

42. The output is directly proportional to the control current.

43. To the control winding, $1C$–$2C$, of the power amplifier $1SX$.

44. The output of $1SX$ is inversely proportional to the control current.

45. (a) Saturates the core of $1SX$. (b) Decreases. (c) Increases.

46. (a) Increases. (b) Decreases. (c) Increases. (d) Decreases. (e) Decreases.

47. (a) Increases. (b) Increases. (c) Increases. (d) Increases.

48. To eliminate circulating cross currents between two systems operating in parallel.

49. Zero.

50. (a) Increases. (b) Decreases. (c) Increases. (d) Decreases. (e) Increases. (f) Decreases. (g) Increases. (h) Decreases. (i) Decreases. (j) Increases. (k) Decreases to zero.

CHAPTER 7

GYROCOMPASS EQUIPMENT

1. (1) Control, (2) alarm, (3) followup, and (4) transmission systems.

2. (1) Motor-generator, (2) speed regulator, (3) control panel, (4) battery throwover panel, and (5) bridge alarm indicator.

3. Ship's 3-phase, 120-v, 60-cycle and 24-v battery.

4. (1) Induction motor, (2) d-c emergency motor, (3) a-c generator, (4) d-c generator, and (5) bedplate.

5. (a) Three-phase, 55 volt, 195-cycle power. (b) Own field excitation, a-c generator field, azimuth-motor field, damping eliminator, azimuth-motor cutout relay, DRE, and the voltage coil of the speed regulator.

6. To maintain a constant output of the a-c generator to drive the gyro motor.

7. By means of a large knurled nut that bears against a hinged plate that, in turn, bears against the carbon piles.

8. By means of two adjusting nuts that increase or decrease the spring pressure of the armature lever arm to decrease or increase the pressure on the carbon piles, thereby decreasing or increasing the resistance in the rotor circuit.

9. (1) The ship's 3-phase supply is disconnected from the motor generator, (2) the battery supply is connected to the d-c motor, which therefore drives the motor generator, and (3) the alarm bell sounds.

10. (1) Throwover to emergency battery because of a reduction of more than 10 percent of the ship's supply frequency or voltage, or both, (2) failure of the ship's supply to the synchro repeaters, (3) failure of the ship's 3-phase, a-c supply, and (4) failure of the compass follow-up system.

11. The 24-volt battery.

12. To drive the phantom element of the master compass in azimuth to aline it with the sensitive element.

13. The followup transformer on the master compass.

14. Provides the controlled power necessary to operate the azimuth motor.

15. (a) 180° out of phase. (b) To obtain zero output voltage when the sensitive element and the phantom element are in proper alinement.

16. (a) The output voltage is equal to the difference between the two coil voltages, and (b) the phase corresponds to that of the larger of the two voltages.

17. (a) Two. (b) One for each direction of rotation of the followup motor. (c) Push pull.

18. (a) Parallel. (b) To provide continuous operation in the event of failure of one thyratron.

19. Opposite.

20. (a) Decrease. (b) Increase. (c) Positive going. (d) *GR*1 and *GR*2. (e) Because both plates are negative.

21. (a) Because both plates are negative. (b) Because both plates are negative. (c) Negative going. (d) They are cutoff.

22. (a) The a-c bias equalizes the plate currents in *GR*1–*GR*2 and *GR*3–*GR*4 to a small keep-alive value. (b) It reduces the torque to zero.

23. To provide an antihunt voltage for the power tubes to prevent hunting and overtravel.

24. The system would continue to operate.

25. To provide a means of transmitting the readings of the master compass to the various repeater compasses.

26. The 1-speed and the 36-speed synchro transmitters on the master compass.

27. To provide a visual alarm that indicates trouble in the transmitter circuit.

28. So that the repeater compasses can be connected either to the master-compass transmitter or to the relay transmitter.

29. To actuate a number of compass repeaters without placing this load directly on the master-compass transmitters.

30. (1) One-speed synchro, *CT*, (2) 36-speed synchro *CT*, (3) commutator transmitter, (4) followup motor, and (5) reactor.

31. (a) To drive the relay transmitter into synchronism with the master compass. (b) The controlling signal voltage from the master compass. (c) The output of the control transformers. (d) The followup motor. (e) (1) The commutator type transmitter and (2) the secondaries of the 1-speed and 36-speed control transformers. (f) The compass repeaters. (g) A Gramme ring winding with taps each of which is connected to a commutator segment. (h) They are similar. (i) To stabilize the current supplied to the commutator transmitter with varying load.

32. (a) A voltage amplifier and a power amplifier. (b) To control the magnitude of the signal voltage applied to T1.

33. (a) They are equal. (b) They are equal. (c) Zero. (d) They are equal. (e) Zero.

34. Because the plates of $V1$ are negative and no conduction occurs.

35. (a) $V1A$ will decrease and $V1B$ will increase. (b) Minus at the top and plus at the bottom. (c) $GR1$ goes more positive and $GR2$ more negative. (d) $GR1$ increases; $GR2$ decreases. (e) Because $GR1$ conducts for a longer period than $GR2$ during the conducting half cycle.

36. To prevent overtravel and hunting of the followup motor.

37. (a) The 36-speed CT. (b) They short-circuit the output of the 36-speed CT to permit the 1-speed CT to control the operation of the followup motor. (c) They act as an open circuit. (d) To prevent the 2-speed system from locking in at 180° error angle and to cause it to drive to the true point of correspondence which is zero degrees.

38. (a) To sound an alarm when the relay transmitter loses synchronism with the master-compass transmitter. (b) From 0° to 2.5°. (c) The stator receives its signal from the 36-speed output of the relay transmitter, and the rotor receives its signal from the 36-speed master-compass transmitter. (d) By means of two trolleys spaced a predetermined distance apart that bear on the periphery of a bakelite disk mounted on the differential-receiver shaft.

39. (1) Motor-generator, (2) speed-control mechanism, and (3) control panel.

40. Three-phase, 120-volt, 205-cycle power.

41. (1) To maintain the speed of the induction motor constant for any given latitude, and (2) to manually change the speeds of the gyro rotors to correspond with the latitude of the ship.

42. By turning the latitude dial until it indicates the ship's latitude.

43. (a) They are series resonant. (b) They short it out. (c) Zero.

44. (a) It decreases. (b) It decreases. (c) C. (d) A rotating field is developed that causes the motor to rotate. (e) Decrease. (f) They are restored to normal.

45. To improve the motor power factor and decrease the current drawn from the gyro supply.

46. Because the generator speed is reduced at high latitudes.

47. (a) To indicate the operating conditions of the master compass. (b) When the flow of oil between the damping tanks is cut off. (c) By turning the switch to the various test positions until the position is reached that silences the alarm bell. (d) Below the first row of switches. (e) To keep the generator field disconnected until the motor comes up to speed at which time the field is cut in. (f) To enable the rectifier tube filaments to be heated before the plate potential is applied. (g) When the compass is used for fire control requiring extreme accuracy. (h) At the bottom of the panel. (i) To ensure that the generator will come up to speed; otherwise it might not supply sufficient voltage to operate the speed-control mechanism.

48. To drive the spider of the master compass in azimuth to aline it with the sensitive element.

49. (1) Voltage amplifier, (2) power amplifier, and (3) antihunt unit.

50. (1) Rate of turn switch, (2) amount of turn switch, and (3) speed acceleration damping cutout unit.

51. The contacts in both the rate of turn switch and the amount of turn switch close to complete the circuit to the damping cutout valve, which operates to eliminate damping during the turn.

52. To operate the damping cutout valve to eliminate damping during rapid changes in the ship's speed.

53. (1) Type 5N synchro receiver, and (2) slow-speed a-c motor.

54. The primaries of the azimuth and gimbal stabilization followup transformers respectively.

55. To sound an alarm when a displacement of more than $\frac{1}{2}°$ occurs between the followup coil and the sensitive element.

56. To keep the rectifier tubes warmed up at all times and in readiness to respond to a signal.

57. (a) Conduction in *GR*1 increases. (b) *GR*2 does not conduct because the plate of *GR*2 is negative.

58. (a) Conduction ceases because its plate is negative. (b) No conduction occurs; the grid of *GR*2 is negative (below cutoff).

59. (a) The motor armature current predominates in one direction, thereby developing a torque to rotate the armature. (b) Decreases the input signal to zero. (c) The plate current of *GR*1 and *GR*2 equalize; the armature currents become equal and opposite on alternate half cycles; and the average torque on the motor armature reduces to zero.

60. When the azimuth rectifier tube indicator reads, "tube 1 on—tube 2 off" and tube 1 shows no evidence of gas ionization.

61. (a) To shift the phase of the antihunt feedback signal 90° before impressing it on the primary of *T7B*. (b) They are 180° out of phase.

62. To indicate failure of the followup systems or of the ship's power supply.

63. To open the stabilization alarm circuit for tests and adjustments, and warming up the amplifier when the stabilizer mechanism is disengaged at the master compass.

64. (1) Three commutator transmitters (navigation, target designation, and radar), (2) a 1-speed followup head mounted on a synchro receiver, (3) a 36-speed followup head mounted on a synchro receiver, and (4) a followup motor.

65. The course input from the 1-speed and 36-speed master compass transmitters.

66. To control the operation of the followup motor that drives through gearing the three commutator transmitters in the relay transmitter.

67. (a) By feeding a signal to the 36-speed synchro that causes shaft contacts 1 or 3 (depending on the direction of rotation) to close head contacts 2 instead of head contacts 4. This action applies single-phase power to the 3-phase motor, causing it to operate as a split-phase motor. (b) Shaft contact 1 (for clockwise rotation) pushes back head contacts 2 until shaft contact 3 closes head contacts 4. This action applies 3-phase power to the followup motor.

68. (1) Ordnance, (2) navigation transmitters of its own master compass, and (3) navigation transmitter of the other master compass.

CHAPTER 8

DEAD RECKONING SYSTEM

1. To provide a means of indicating the ship's position in latitude and longitude on an appropriate chart or on mechanical dials.

2. (a) (1) The distance traveled by the ship and (2) the ship's course. (b) The underwater log and the master compass respectively.

3. (1) Dead reckoning analyzer, (2) dead reckoning indicator, and (3) dead reckoning tracer.

4. (1) The ship's distance input from the underwater log and (2) the ship's course input from the master compass.

5. (1) North-south and (2) an east-west.

6. (1) Distance converter, (2) roller carriages, and (3) ship's course crank arm mechanism.

7. To drive the counter, J, and the disks, $M1$ and $M2$, the rotation of which is proportional to the distance traveled.

8. (a) By a crank arm mechanism controlled by the signal from the master compass. (b) The north-south component of the ship's speed. (c) The east-west component of the ship's speed.

9. (a) $L1$ is at the edge of its component disk $M1$, and $L2$ is at the center of $M2$. (b) Maximum. (c) Zero.

10. In the tracking mechanism of the dead reckoning tracer.

11. (1) Latitude motor and dials, (2) longitude motor and dials, and (3) latitude correction mechanism.

12. (1) The outputs of the north and east transmitters (2) drive the latitude and longitude receivers respectively.

13. To reverse the direction of rotation of the latitude dials when the equator is crossed.

14. To adjust the number of miles east-west per degree of longitude in accordance with the latitude of the ship because the relation between a degree of longitude and a degree of displacement of the longitude receiver varies with the latitude.

15. (1) Tracking mechanism, (2) chart board and pencil carrier assembly, and (3) auxiliary plotting board.

16. (1) The inputs from the north and east transmitters in the DRA (2) drive the step receivers that operate the mechanisms that record a graphical plot of the distance and direction traveled by the ship.

17. (1) The cross-screw drive unit assembly and (2) the lead-screw drive unit assembly.

18. To provide a means of changing latitude and longitude scales to which the ship's course can be plotted.

19. To interchange the north and east component inputs from the DRA to shift the plotting axes.

20. The entire pencil carriage assembly, to the right or left.

21. (1) The pencil carrier, up or down.

22. The north and east components respectively of the ship's travel.

23. In the left-hand section of the DRT case below the pencil carrier assembly.

24. (1) Pencil, (2) pencil magnet, and (3) range-bearing projector.

25. By means of a clock-driven switch that energizes the pencil magnet circuit at predetermined intervals.

26. For use with the auxiliary plotting board to indicate own ship's position at all times.

27. To plot ranges and bearings of surface targets obtained from points along own ship's course.

28. To project an image on an appropriate chart placed on the auxiliary plotting board.

29. To plot the range and bearing of a target with respect to own ship from the center dot of the image.

CHAPTER 9

DIAL TELEPHONE RELAYS AND SWITCHES

1. Nonmultiple switchboard.
2. Multiple switchboard.
3. (1) Pairs of cords and plugs with the associated talking and ringing keys, (2) supervisory signal lamps, and (3) operator's talking sets.
4. (a) Tip, ring, and sleeve connections. (b) The tip and ring of the cord circuit carry the two line wires; the sleeve is a local control wire used for certain operations within the cord circuit.
5. To prevent voice currents from flowing through the common battery, but to allow these currents to flow in their respective cord circuits.
6. The Strowger two-motion type of switch on a step-by-step basis in synchronism with impulses that originate at the dial of the calling telephone.
7. An electromagnetic device used to automatically open or close electrical circuits to other relays or equipment.
8. (1) Coil and core, (2) heelpiece, (3) armature, and (4) spring assembly.
9. (1) Make, or front; (2) armature, or movable; and (3) break, or back springs.
10. Make springs close their contacts and break springs open their contacts.
11. (a) Spring pileup. (b) 13 springs in one pileup. (c) 10 springs in each of two pileups.
12. (1) Break springs, (2) make springs, (3) break-before-make springs, and (4) make-before-break springs.
13. (1) Fast-acting, (2) slow-acting, and (3) a-c.
14. A slow-acting relay; a copper collar or slug is placed around the armature end of the core to delay operation of the relay armature when the coil is energized.
15. A slow-acting relay; a copper collar or slug placed around the heelpiece end of the core or a copper sleeve placed along the entire length of the core under the coil to delay the release of the relay after it has been deenergized.

16. (1) A laminated iron core to minimize eddy currents, and (2) a shading coil on the armature end of the core to prevent the armature from vibrating.

17. To increase the release delay to a value that is greater than can be obtained by a heelpiece end copper collar or a copper sleeve.

18. To operate two sets of contact springs.

19. (a) A relay that does not operate all of the contact springs at the same time. (b) A line operates partially when the handset is removed; after the calling line has been located and extended to the connector, the line relay operates the remainder of its contacts.

20. (a) Relay equipped with two contacts on each spring to obtain a greater current-carrying capacity than that provided with single contacts.

21. A relay designed to occupy a smaller space than is required by a standard horizontal relay.

22. The positioning (bending) of the stationary springs so that the armature springs exert pressure against the break contacts when the relay is released, and so that the armature springs exert pressure against the make contacts when the relay is operated.

23. The tensioning of the armature springs to provide satisfactory operation of the relay armature between two specified values of control-coil current.

24. (1) Finder, (2) connector, (3) selector, and (4) minor switches.

25. (1) Bank assembly, (2) switch mechanism and (3) control relays.

26. (a) Private and line banks and (b) private, line, and vertical banks.

27. 100 sets of double contacts each.

28. In rows, ten sets high and ten sets wide.

29. One set of wipers for each bank.

30. (a) Each individual contact is insulated from the other contacts. (b) At the rear end of the bank.

CHAPTER 10

DIAL TELEPHONE LINE STATION EQUIPMENT

1. (1) Type A desk telephone, (2) type B bulkhead telephone, (3) type C watertight bulkhead telephone, (4) type D intercommunicating telephone, and (5) type E compact telephone.
2. (a) One-party service and (b) two-party service.
3. (1) Ringing circuit, (2) dialing circuit, (3) talking circuit, and (4) receiving circuit.
4. From $L1$ to the line and cord terminal block, to the ringing capacitor, $C1$, through the upper contact of the cradle switch to the ringer, back to the line cord and terminal block, and to $L2$.
5. From $L1$ to the line and cord terminal block, through the lower contact of the cradle switch, to the dial impulse springs, and through the right-hand contact of the dial shunt springs, back to the line and cord terminal block, and to $L2$.
6. To shunt out the transmitter, receiver, and induction coil when the dial is returning to normal after it is released.
7. To produce an impulse each time the impulse springs are opened when the dial is returning to normal.
8. From $L1$ to the line and cord terminal block, through the lower contact of the cradle switch, to the dial impulse springs, through winding 1–2 of the induction coil, to the transmitter, back to the line and cord terminal block, and to $L2$.
9. From $L1$ to the line and cord terminal block, through the lower contact of the cradle switch, through the impulse springs, to winding 1–2 of the induction coil, to the transmitter back to the line and cord terminal block, and to $L2$.
10. A motor-operated horn.
11. Yes.
12. 120-volt a-c or d-c power.
13. The power signal relay operates on the ringing current supplied to the line when the line station is signaled and closes the 120-volt circuit to the extension signal.
14. To avoid the possibility of the inductive discharge of the line relay from affecting the power signal relay during dialing and causing intermittent operation.
15. To provide a combined dial telephone and intercommunicating station.
16. Three stations.

17. (1) Desk unit and (2) bulkhead unit.
18. By operating the talk switch each time the unit is used for transmission.
19. As a microphone.
20. As a loudspeaker.
21. By operating the handset transfer switch to the I.C. system position and removing the handset from the cradle switch.
22. At the talking station.
23. By replacing the handset on the cradle switch and operating the handset transfer switch to the dial telephone position.
24. (1) As an extension telephone to an associated main line telephone and (2) as a main line telephone.
25. By rolling the cord back and forth between the hands while listening for a crackling noise in the receiver.
26. Failure of the shunt springs to make contact when turning the dial.
27. (1) Open ringer coil, (2) open capacitor, (3) improper ringer adjustment, (4) reverse or loose ringer connections, and (5) loose or shifted gongs with respect to the clapper.
28. (1) Shorted transmitter, (2) shorted contact of the dial shunt springs, and (3) failure of the monophone springs to operate and cut off the ring when the handset is removed from the cradle switch.
29. (1) Improper contact of the contact springs in the receiver, (2) loose receiver cap, (3) worn receiver cord, and (4) loose connections inside the telephone.
30. (1) Stuck carbon granules in the transmitter unit and (2) loose connection of the contact springs in the transmitter unit.
31. Failure of line relay to operate.
32. To prevent the unnecessary operation of the automatic switches that seize and hold busy a conversation link at the switchboard.

CHAPTER 11

DIAL TELEPHONE AUTOMATIC SWITCHBOARD

1. Local, (2) outgoing, (3) incoming, (4) executive priority, and (5) hunt-the-not-busy line services.
2. The first digit dialed energizes a minor switch that determines the side of the line that is supplied ringing current; the second

and third digits dialed cause the connector switch to step UP and IN on the connector switch bank to the desired line.

3. Over the positive side of the line and ground.
4. The negative and positive sides of the line.
5. (1) Finder board and (2) connector board.
6. (1) Line relay and (2) cutoff relay.
7. Two.
8. (a) The first step. (b) It closes certain contacts that cause the line-finder equipment to operate.
9. (a) The second step. (b) It disconnects them.
10. (a) The second step. (b) It disconnects them. (c) To prevent operation of the line-finder equipment.
11. Twenty-five.
12. (1) To find and (2) to connect a line that demands service to an idle connector.
13. The finder control and distributor equipment.
14. (a) 13 and (b) 12.
15. (a) 50 and (b) 50.
16. An idle finder in group B will step UP and IN on this particular line in group B.
17. To control the vertical and rotary movements of the pre-selected finder.
18. To assign the finder switches successively to the calls as they are originated.
19. Three-ampere, alarm-type indicating fuse.
20. (1) Commissioning calls and (2) normal calls.
21. The cradle switch is closed when the handset is removed at the calling station.
22. From contacts 3–4 of relay Z_c (released) in the connector (fig. 11–7).
23. From contacts 9–10 of relay *L*2.
24. Contacts 4–5 of relay *RS*1*A* (energized).
25. *X* contacts (3–4) of relay *L*2 (energized partially).
26. Contacts 3–4 of relay *T*4.
27. Contacts 7–8 of relay *G*4 and contacts 1*B*–2*B* of relay *T*4.

28. Contacts 4–5 of relay $RS1A$ (energized).

29. Contacts $1T$–$2T$ of relay $T4$ (energized).

30. Contacts $3T$–$4T$ of relay $T4$.

31. Contacts $4B$–$5B$ of relay $D6$ through the 500-ohm N.I. resistance across the —L and +L leads and contacts 5–6 of relay G_c to ground.

32. Contacts 4–6 of relay G_c in the connector over the dial tone lead through $SJ15$.

33. Contacts 7–8 of relay $H4$.

34. The C wiper rotates to make contact with negative battery from winding 1 of relay $L2$, on the TEST lead to relay $J4$.

35. The circuit to winding 1 of relay $L2$ is completed through the TEST lead in series with relay $J4$.

36. Contacts 2–3 of relay $J4$ over the SW lead.

37. Contacts $5T$–$6T$ and $7T$–$8T$ of relay $C6$ over the +L and —L lines from the calling station through to the succeeding switch.

38. Contacts $3B$–$4B$ of relay $C6$ through VON springs 3–4.

39. $SJ15$.

40. Contacts 7–8 of relay B_c in the connector by way of contacts $3T$–$4T$ of relay $C6$.

41. Contacts $5B$–$6B$ of relay $C6$ (energized) through contacts 7–8 of B_c in the connector (fig. 11–7).

42. Contacts 2–3 of relay $B4$ (energized).

43. Contacts 6–7 of relay $FD2$ (energized).

44. Contacts $3T$–$4T$ of relay $T4$ (released).

45. Contacts 3–4 of relay $FD1$ (released).

46. Ground on the G lead puts a hold on relay B4.

47. Contacts 1–2 of relay $RS2A$.

48. Contacts $1B$–$2B$ of relay $C6$ (released) through the finder VON springs 1–2.

49. Contacts $5B$–$6B$ of relay $T4$.

50. Contacts 3–4 of relay $F4$ (released).

51. Contacts 3–4 of relay $F4$ (released) connect the STA and STB leads together to complete the circuit to relay $E4$ in group B; contacts 4–5 open the circuit to relay $E4$ in group A.

52. Contacts 10–11 of relay $F4$ in group A (released) remove ground over the L5BG lead to remove the fifth level mark circuit of the group B finders.

53. When any one of the group A finders becomes free, ground is placed on the ATBG lead through contacts 3–4 of relay Z_c in the connector to complete a circuit to relay $F4$ in group A.

54. Relays $C4$, $D4$, $L4$, *and* $U4$.

55. From 4 to 11 seconds.

56. Contacs 5T–6T of relay $U4$ (energized) through windings 1 and 2 of relay $C4$.

57. X contacts (1–2) of the next FD relay ($FD4$ in this case).

58. Contacts 1–2 of relay $C4$ (energized).

59. Contacts 5–6 of relay $C4$ (released).

60. Opens the circuit to relay $U4$ and routes the calls to the group A finders again after the defective finder has been determined.

61. In rotary hunting, failure of the finder to find a line marked by negative battery, for example, because of insulated wiper contacts.

62. Contacts 1–2 of the finder cam springs.

63. Ten line relays.

64. Contacts 1–2 of relays $F4$ and $F4$A over the AFB lead.

65. Contacts 4–5 of relay $FB9$ through the induction coil to the calling line.

66. To prevent the AFB tone from leaking into other circuits.

67. To complete the connection between the calling station and the called station, and to control the release of the connection.

68. A link.

69. To provide selective ringing of two-party lines and to select the side of the line that is supplied ringing current.

70. Contacts $4B$–$5B$ of relay $D6$ in the finder.

71. Contacts 4–6 of relay C (energized).

72. Relays A_c, B_c, C_c and G_c.

73. Contacts 1–2 of relay A_c (released).

74. MSON springs 1–2.

75. Contacts 1–2 of relay Z_c.

76. Contacts 4–6 of relay G_c (released).
77. Contacts 1–2 of relay A_c (released).
78. Connector SVON springs 5–6.
79. Contacts 1–2 of relay A_c (released).
80. Contacts 4–5 of relay E_c (energized).
81. Contacts 1–2 of relay H_c (released).
82. Contacts 2–3 of relay B_c (energized).
83. Contacts $1T$–$2T$ of relay M_c.
84. Contacts $7T$–$8T$ and $8B$–$9B$ of relay M_c operating fully and locked.
85. Contacts $4B$–$5B$ of relay M_c.
86. Contacts $6B$–$7B$ of M_c.
87. When the C wiper encounters positive ground as it moves onto the bank contacts of the called line.
88. Contacts 5–6 of relay H_c (released).
89. In series.
90. Any first digit other than 9.
91. First digit 9.
92. X contacts (1–2) of relay F_c (partially energized).
93. Contacts 3–4 and 6–7 of relay F_c (energized completely).
94. Contacts 4–5 and 7–8 of relay F_c (energized completely).
95. Contacts 9–10 of relay F_c (operated fully).
96. Contacts 2–3 of relay D_c (energized).
97. Contacts 4–6 and 7–9 of relay D_c (energized).
98. When the calling party releases first and the circuit is opened by the hookswitch.
99. Contacts 2–3 of relay B_c (released).
100. Contacts 11–12 of relay B_c (released).
101. Contacts $5T$–$6T$ of relay M_c (released).
102. Contacts $7T$–$8T$ and $8B$–$9B$ of relay M_c (released).
103. Contacts $6B$–$7B$ of relay M_c (released).
104. Contacts 2–3 of relay D_c (released).
105. SVON springs 3–4.

106. MSON springs 1–2 (restored).

107. At the hookswitch of the called party.

108. The calling party.

109. Contacts 2–3 of relay A_c (released).

110. Contacts 2–3 of relay B_c (released).

111. Contacts 4–5 of relay B_c (released)

112. MSON springs 1–2 (released).

113. Contacts $1B$–$2B$ of relay $C6$ (released).

114. By strapping the C and EC leads together at the finder bank terminal strip of the telephone requiring this service.

115. Contacts 7–8 of relay B_c (energized).

116. When the C wiper of the connector encounters positive ground on the bank contacts of the called line.

117. Contacts 7–8 of relay H_c (released).

118. Contacts $2B$–$3B$ and $5B$–$6B$ of relay L_c (energized).

119. Contacts $1T$–$2T$ of relay L_c (energized).

120. Contacts 7–8 of relay K_c (released).

121. The calling telephone on dialing the lower number in a hunt-the-not-busy line group is connected to a free telephone in that group.

122. (1) The selected telephone lines must terminate on the same bank level; (2) they must be arranged in numerical sequence; (3) the CN and ECN leads of all but the last telephone must be strapped together at the connector bank terminal strip; (4) the last telephone in the group is not trunk hunting.

123. Contacts 1–2 of relay E_c (released).

124. Contacts 3–4 of relay J_c (energized).

125. (1) The rotary magnets step the wipers to the next trunk in the group and (2) the interrupter springs 1–2 open the operating circuit to relay J_c.

126. The absence of positive ground on the ECN bank contact because the last telephone in the group is not trunk hunting.

CHAPTER 12

DIAL TELEPHONE ALARM, RINGING, AND TESTING EQUIPMENT

1. To give an alarm if a nonstandard condition exists in the telephone system.
2. Audible and visual signals to indicate the nature and general location of the trouble.
3. When any fuse blows.
4. When a finder or connector fails to release after the normal releasing time of the switch has elapsed.
5. To provide predetermined delay intervals automatically for each type of alarm that requires a delay.
6. On the lamp and key panel mounted on the front of the finderboard.
7. (1) If the switchboard battery voltage drops below a pre-determined value or (2) if the power supply fuse blows.
8. Any blown fuse on the power panel, except the voltmeter fuse.
9. (1) Failure of the ship's 120-volt power supply, (2) operation of the controller overload contacts (or blown controller fuse), and (3) failure of the generator to cut in after the motor-generator has started.
10. Supervisory alarms for the power equipment.
11. Any blown fuse on the fuse panel.
12. Failure of the connector or finder switch to release when the associated magnet circuit is closed.
13. By plugging the hand test telephone in the correspondingly numbered connector test jack (with button C depressed) of each finder that is off normal. If no conversation is heard, release button C and challenge. If no answer is received, manually release the switch that is off normal.
14. Failure of the finder (allotted to a call) to function or complete its function.
15. To "busy out" the finder-connector link until the defective finder can be repaired or replaced.
16. Any condition that causes a finder-connector link to be held in an operated position when it is not being used for talking or dialing purposes.

17. Failure of the ringing machine to start or supply ringing current to the ringing transformer.
18. Operate the ringing machine transfer switch to start the idle ringing machine and restore service to the switchboard.
19. To provide an audible signal in addition to the visual signals when a nonstandard condition exists in the telephone system.
20. (1) Dial tone, (2) ring-back or ringing tone, and (3) busy tone.
21. To provide a 1-second ringing period and a 3-second silent period in the ringing current.
22. To provide approximately two interruptions per second of the dial tone to distinguish it from the dial tone.
23. To provide a 4-second time pulse to operate the timer relays.
24. The calls through the switchboard.
25. To operate the idle ringing machine independently of the machine in service for periodic tests or repairs.
26. To control the ring and tone machine timer, and alarm circuits and the associated timer circuit.
27. Relay T13.
28. (1) Completes its own lock circuit, (2) opens its own operating circuit, and (3) completes the operating circuit to the next even-numbered relay, but that relay does not operate at this time.
29. Completes the holding circuit to the next even-numbered relay.
30. The next odd relay either operates or releases.
31. The next even relay either operates or releases.
32. Relay *T*14.
33. The timer interrupter springs place ground (positive battery) on the TP lead every 4 seconds through contacts 4–3 of relay *T*14 and contacts 6*B*–7*B* of relay *RC*3.
34. Contacts 8–9 of relay *T*2 (released).
35. Contacts 4–5 of relay *T*4 (energized).
36. Contacts 4–6 of relay *T*5 (energized).
37. Contacts 1–2 of relay *T*14.
38. Resistor F through contacts 4–5 of relay *RC*2 (energized).
39. *X* contacts (1–2) of relay *RC*2 (energized).
40. Contacts 4–5 of relay *RC*1 (released).

41. Contacts *2B–3B* of relay *RC3*.

42. Contacts *4B–5B* of relay *RC3*.

43. To prevent a-c relay *RM2* from chattering.

44. Limits the current to protect the rectifier.

45. The cam-operated interrupter springs on the ringing machine.

46. Contacts 1–2 or 3–4 of relay *RM4* (released).

47. Contacts 5–6 of relay *RM4* (released).

48. Contacts 1–2 of relays *PC1* and *PC4* on the power panel.

49. Contacts 1–2 of relay *CS2*.

50. Contacts 1–2 of relay *CS3* (released).

51. Leads BTC and +BAT respectively.

52. *S*J31.

53. Contacts 4–5 of relay *FB9* (released).

54. Leads DTC and +BAT respectively.

55. When a line finder release magnet operates, release signal springs 1–2 of the finder release magnet place ground on the FR SIG lead.

56. Contacts 7–8 of relay *R2* (energized) place ground on the TST lead.

57. Contacts 2–3 of relay *T1* (energized) place ground on the D1 lead.

58. Contacts 3–4 of relay *R4* (energized) through winding 2.

59. Contacts 9–10 of relay *R3* (energized).

60. Contacts 1–2 of relay *R4* (released).

61. Normally, contacts 1–2 of relay B_c (released) place ground on the CR SIG lead.

62. Contacts 9–10 of relay B_c (energized) place a ground on the C PERM lead.

63. Contacts 2–3 of relay *T1* (energized).

64. At the permanent reset key.

65. Contacts 3–4 of relay *P3*.

66. Contacts 6–7 of relay *P2* (released).

67. (1) Line disconnect key panel, (2) hand test telephone, (3) test set, and (4) portable resistance test box.

68. 100 line disconnect keys.

69. To disconnect any line from the switchboard for (1) testing, (2) isolating a faulty line, and (3) cutting out nonessential lines.
70. A capacitor is connected in the transmitter circuit to cut off the talking circuit to permit listening only and to prevent interference with the dial pulses when plugging in the hand test telephone.
71. A 1200-ohm resistor is connected in series with the transmitter for testing Strowger switches.
72. For weekly routine testing of connectors and for weekly call through tests of finders and connectors.
73. Trunk hunting test.
74. Number 29.
75. To prevent interference with the conversation through the busy connector, under test.
76. A function similar to that of the hookswitch of the called telephone.
77. Simulated talk relay.
78. A function that corresponds to that of the hookswitch of the calling telephone.
79. Contacts 1–2 of relay B_{ts} (released).

CHAPTER 13
DIAL TELEPHONE POWER AND ACCESSORY EQUIPMENT

1. (1) Motor generator, (2) storage battery, (3) a motor starter, and (4) a power panel.
2. 48 volts.
3. To charge the storage battery.
4. Because the restricted section of the magnetic bridge limits the flux that can pass through it.
5. Because the shunt field predominates at all times.
6. (1) Control relays, (2) a voltmeter, (3) a generator ammeter, (4) a battery ammeter, (5) generator field rheostats, (6) a voltmeter switch, (7) a generator switch, (8) two motor-generator input switches, (9) a generator output switch, and (10) fuses.

7. The battery voltage.
8. The generator circuits are open.
9. To cut in the generator and to place the generator output in parallel with the battery and the switchboard load.
10. (1) Power fail, (2) power fuse, (3) motor-generator fail.
11. Operating the motor-generator INPUT switch manually connects together the P1 and P2 leads.
12. Operating the generator switch to the generator position 1 or 2.
13. 40 volts.
14. (a) Manually operating the generator output switch momentarily. (b) Contacts 1–2 of relay *PC*5 (energized). (c) Contacts 3–4 of relay *PC*5 (energized). (d) Manually releasing the generator output switch. (e) 40 volts. (f) The auxiliary shunt contacts of relay PC6 (energized). (g) The auxiliary contacts of relay *PC*6 (energized). (h) Contacts 4–5 of relay *PC*4 (energized). (i) Contacts 1–2 of relay *PC*5 (released).
15. (a) The auxiliary contacts of relay *PC*6 (released). (b) Because the motor-generator input switch is opened before relay *PC*4 releases to close contacts 1–2 to the alarm (CFR lead).
16. (a) A reverse current of 10 amperes causes the series coil of relay PC6 to oppose its shunt coil sufficiently to release the relay. (b) The auxiliary contacts of relay *PC*6 (released). (c) Contacts 1–2 of relay *PC*4 (released). (d) Contacts 3–5 of relay *PC*4 (released).
17. (1) Operate the motor-generator input switch to the OFF position. (2) Reset the overload coils manually. (3) Operate the motor-generator input switch to the ON position.
18. (a) Contacts 3–4 of relay *PC*2 (released). (b) Contacts 1–2 of relay *PC*2 (released). (c) Relay *PC*2 will reenergize to cut off the power fail alarm.
19. Positive voltage ground is placed on the CFR lead through the 1–2 contacts of relays *PC*1 and *PC*4.
20. Contacts 1–2 of relay *PC*1 (energized).
21. Contacts 3–4 of relay *PC*3 (energized).
22. Contacts 1–2 of relay *PC*3 (released).
23. To establish calls to and from shore exchanges when the ship is in port.
24. The two-way shore-line trunks and the terminal block.

25. The two-way local trunks and the equipment for the attendant's telephone circuit, the fuse panel, terminal block, and a headset.

26. The key panel, the handset, the dial, and a jack for plugging in the headset.

27. Four lamp and key strips.

28. (1) A busy lamp (red), (2) a call lamp (white), (3) two shore trunk (cross connecting) keys, (4) a talk (answering) key, and (5) a release key.

29. Any local trunk can be cross connected with any shore-line trunk and vice versa.

30. The attendant can release either end of a connection while holding the other end.

31. The two lamps provide CALL, BUSY, and DISCONNECT indications. The buzzer provides an audible signal on the CALL and DISCONNECT indications.

32. To switch the attendant's cabinet in and out of service.

33. To protect the line equipment and the attendant from injury that can be caused if the shore lines are subjected to lightning discharges and/or crosses with power circuits.

34. To transfer the line circuits (37, 38, 39, and 30) from the ship's exchange to the attendant's cabinet for calls to and from the ship when in port.

35. Contacts 2–3 of relay $B1$ (energized).

36. Contacts 8–9 of relay $H1$ (energized).

37. Contacts 5–6 and 7–8 of local talk key operated.

38. Contacts $4T$–$5T$ of relay G1 energized.

39. Contacts $4B$–$5B$ of relay $G1$ energized.

40. Relay $A1$ is a polarized relay and both windings must be energized in the same direction.

41. Contacts 1–2 of the attendant's handset hookswitch (operated).

42. Contacts 3–4 and 5–6 of the shore trunk key (operated).

43. Contacts 5–6 and 7–8 of the shore talk key (operated).

44. Contacts 4–5 of relay $B4$ in the attendant's cabinet (energized).

45. Contacts 1–2 of the local talk key (restored).

46. Contacts 2–3 of the dial off-normal (D.O.N.) springs.

47. *X* contacts 1–2 of relay *AT*2 (energized).

48. Contacts 2–3 and 5–6 of relay *A*4 (energized).

49. Contacts 5–6 and 7–8 of the shore talk key (restored).

50. Contacts 2–3 of relay *B*1 (released).

51. Contacts 3–4 and 5–6 of the shore trunk key (restored).

52. Contacts 4*B*–5*B* of relay *G*1 (released).

53. Contacts 8–9 of relay *H*1 (released).

54. Contacts 10–11 of relay *H*1 (released).

55. Contacts 4–5 of relay *B*4 (released).

56. (a) Ringing current from the connector in the shore exchange over the positive and negative leads. (b) Contacts 1–2 of relay *C*4 (energized). (c) Contacts 1–2 of relay *D*4 (energized). (d) Contacts 1–2 of relay *AR*3 (energized).

57. (a) Contacts 3–4 of the shore talk key (operated). (b) Contacts 5–6 and 7–8 of the shore talk key (operated). (c) Contacts 1–2 of relay *AT*1 (energized). (d) Contacts 4–5 of relay *B*4 (energized). (e) Contacts 6–7 of relay *B*4 (energized). (f) Contacts 1–2 of relay *AR*3 (released). (g) Contacts 3–4 of the attendant's handset hookswitch (operated).

58. (a) Contacts 3–4 and 5–6 of the shore trunk key 1 (operated). (b) Contacts 5–6 and 7–8 of the local TALK key (operated). (c) Contacts 2*T*–3*T* of relay *G*1 (energized). (d) Contacts 4*B*–5*B* of relay *G*1 (energized). (e) The local trunk line relay operates partially when relay *G*1 enerigzes to complete the loop circuit. (f) The dial impulses from contacts 4–5 of the attendant's dial impulse springs are sent out over the ship line leads. (g) Contacts 4–5 of relay *AT*2 (released). (h) Contacts 5–6 and 7–8 of the local TALK key (released). (i) The connector reverses the battery polarity to the local + and − leads of the local trunk to energize the winding 1 of relay *A*1 so that both windings now assist each other. (j) The called party and the attendant.

59. (a) Contacts 1–2 of relay *A*1 (released). (b) Contacts 3–4 and 5–6 of shore trunk key 1 (released). (c) Contacts 4–5 of relay *B*4 (released).

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

INTERIOR COMMUNICATIONS ELECTRICIANS (IC)

(CURRENT THROUGH CHANGE NO. 9)

RATING CODE NO. 4200

General Service Rating

IC electricians maintain and repair interior communications (IC) systems, gyro-compass systems, amplified and unamplified voice systems, alarm and warning systems, and related equipment; stand IC and gyro-compass watches.

Emergency Service Rating

Same as General Service Rating.

Navy Job Classifications and Codes

For specific Navy job classifications included within this rating and the applicable job codes, see Manual of Enlisted Navy Job Classifications, NavPers 15105 (Revised), codes IC–4700 to IC–4799.

Qualifications for Advancement in Rating

Qualifications for advancement in rating	Applicable rates IC
100 PRACTICAL FACTORS	
101 OPERATIONAL	
1. Identify insulation materials and varnishes	3
2. Identify electrical cables, wiring, and fittings	3
3. Locate and identify IC equipment and circuits	3
4. Read electrical drawings and sketches	3
5. Operate IC and action cut-out (ACO) switchboards:	
a. Transfer circuits for normal operation and battle conditions	3
b. Set up control circuits for anchor and under way conditions	1
6. Use all electrician's common hand and small bench tools, including soldering irons and electric-powered tools such as drills and grinders	3

Qualifications for advancement in rating	Applicable rates IC
101 OPERATIONAL—Continued	
7. Use voltmeter, ammeter, ohmmeter, megger, and tachometer	3
8. Inspect condition of, and install, dry cell and wet cell batteries	3
9. Extinguish electrical fires using CO_2 extinguishers. (Simulated conditions.)	3
10. Rescue a person in contact with an energized circuit; resuscitate a person unconscious from electrical shock; treat for electrical shock and burns. (Simulated conditions.)	3
11. Energize and start, test for proper operation, operate (making any external adjustments), and secure ship's metering and indicating systems, ship's control systems, alarm and warning systems, amplified voice and projection equipment, and signal system	2
12. Work from electrical drawings	2
13. Use electronic voltmeter, tube tester, multitester, circuit analyzer, oscilloscope, and signal generator	2
14. Prepare diagrams and sketches of IC devices and equipment, using standard designations for cables, wiring, terminal markings, and circuit components	C
102 MAINTENANCE AND/OR REPAIR	
1. Maintain all electrician's hand and bench tools, including soldering copper and electric-powered tools	3
2. Find and clear short and open circuits, and grounds in cables, wiring, fittings, call bells, and buzzers	3
3. Make complete casualty analysis and repair sound-powered telephone hand and head sets	3
4. Cross-connect IC systems to operate under emergency conditions	3
5. Renew section of flexible cable between a junction box and a synchro instrument such as a gyrocompass repeater	2
6. Replace tubes, and handle troubles of starting panel controllers as applied to IC equipment	2
7. Clean, test and lubricate dead-reckoning equipment	2
8. Tighten connections on switchboards and control panels	2
9. Casualty analysis and corrective maintenance on the following:	

Qualifications for advancement in rating	Applicable rates IC
102 MAINTENANCE AND/OR REPAIR—Continued	
a. Alarm and warning systems—contact makers, audible signal, and indicators	2
b. Voice recorders and record players	2
c. Sound motion picture projectors (16-mm.)	2
d. Intercoms and portable announcing equipment	2
e. Ship control order and indicating system	2
f. Repeater units (synchros)	2
g. Motor-generator sets and rotary converters (no disassembly) and control panels as applied to IC equipment	2
h. Sound-powered telephone circuits except sector control and CIC circuits	2
i. Constant frequency control	1
j. Underwater logs	1
k. Wind indicators	1
l. Central amplifier system	1
m. Automatic telephones and all sound-powered telephone circuits	1
n. Gyrocompass and associated devices	C
10. Install necessary leads for connecting a synchro transmitter to two independent synchro receivers through a rotary switch	1
11. Test, remove, and install meters and instrument transformers	1
12. Make periodic inspections and adjust IC units	C
103 ADMINISTRATIVE AND/OR CLERICAL	
1. Maintain all required records at watch station	3
2. Request replacement parts for IC devices	3
3. Use electrical publications furnished to the electrical division for selecting materials and identifying equipment parts	3
4. Take charge of IC room while under way	2
5. Take charge of all gyrocompass and IC watches	1
6. Supervise the setting up of public address systems	1
7. Prepare job requisitions or work orders for both tender and shipboard repair to IC or gyrocompass equipment	C
8. Supervise and train personnel in operation, maintenance, and/or repair of IC and gyrocompass equipment	C

Qualification for advancement in rating	Applicable rates IC
103 ADMINISTRATIVE AND/OR CLERICAL—Continued	
9. Estimate time, material, and labor required for the repair of gyrocompass and IC systems and equipment	C
10. Plan, organize, and direct work of personnel operating, maintaining, and repairing IC and gyrocompass systems	C
200 EXAMINATION SUBJECTS	
201 OPERATIONAL	
1. Procedures and safety precautions involved in performing tasks appropriate to the applicable rates listed under 100 Practical Factors	---------
2. Nomenclature and function of IC devices and associated equipment	3
3. Function and use of voltmeter, ammeter, ohmmeter, megger, and tachometer	3
4. Classifications, markings, and functions of IC circuits	3
5. Theory of direct and alternating current; principles and application of electromagnetic induction; relationship of current, voltage, and resistance in d. c. circuits; effects of resistance, capacitance, and inductance in simple a. c. circuits	3
6. Types and uses of electron tubes in IC systems	3
7. Relation between filam ent (cathode) plate and grid in electron tube	3
8. Transferring circuits on IC and ACO switchboards for normal operation and battle conditions	3
9. Operating principles of power units such as motor-generator sets, control panels, transformers, and rectifiers as applied to IC equipment	3
10. Procedures for energizing, starting, testing for proper operation, and securing IC systems	3
11. Fundamentals of power distribution systems aboard naval vessels	3
12. Function and use of oscilloscope, tube tester, circuit analyzer, electronic voltmeter, multitester, and signal generator	2
13. Principles of IC polyphase circuits	2

Qualifications for advancement in rating	Applicable rates IC
201 OPERATIONAL—Continued	
14. Types and uses of gas-filled tubes and cathode-ray tubes in IC systems	2
15. Theory and principles of operation of IC systems: Underwater log, wind indicators, automatic telephones, gyrocompasses, and central amplifier announcing systems	C
202 MAINTENANCE AND/OR REPAIR	
1. Care and stowage of IC materials	3
2. Casualty analysis and corrective maintenance for the following IC equipment:	
a. Cables, wiring, and fittings	3
b. Sound-powered telephone hand and head sets	3
3. Procedures for cross-connecting IC systems under emergency conditions	2
4. Procedures for replacing electron tubes	2
5. Corrective maintenance on the following:	
a. Alarm and warning systems—contact makers, audible signals, and indicators	2
b. Voice recorders and record players	2
c. Sound motion picture projectors (16-mm.)	2
d. Intercoms and portable announcing systems	2
e. Sound-powered telephone circuits except sector control and CIC circuits	2
f. Ship control order and indicating system	2
g. Repeater units (synchros)	2
h. Motor-generator sets, rotary converters, and control panels as applied to IC equipment	2
i. Constant frequency control	1
j. Wind indicators	1
k. Audio amplifier systems	1
l. Automatic telephones and all sound-powered telephone circuits	1
m. Gyrocompass and associated devices	C
n. Underwater logs	C
o. Magnetic amplifiers	C
6. Preventive maintenance and operating adjustments of standard naval test equipment used by IC personnel	1
7. Daily, weekly, monthly, quarterly, semiannual, and annual tests required on IC circuits and equipment	1

Qualifications for advancement in rating	Applicable rates IC
202 MAINTENANCE AND/OR REPAIR—Continued	
8. Methods and procedures for the overhaul of IC and ACO switchboards	C
9. Methods and procedures for adjusting voltage regulators	C
203 ADMINISTRATIVE AND/OR CLERICAL	
1. Use of allowance lists for determining repair parts, tools, and supplies kept on board	C
2. Procedures for obtaining replacement parts and supplies; maintenance of inventory	C
3. Standard IC records and reports maintained aboard ship	C

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